UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

CONFERENCE ON RECENT ADVANCES IN COTTON UTILIZATION RESEARCH

Held At

Jung Hotel

New Orleans, Louisiana

May 1-2, 1961

C O N T E N T S

F O R E W O R D

These proceedings report the information on advances in cotton utilization research presented at the general conference held on May 1-2, 1961, as a part of the annual review of cotton research by the official advisors to the Southern Utilization Research and Development Division. In addition to the advisors, the general conference was attended by some 120 invited representatives of the textile and related industries, educational and other research institutions, other governmental agencies, as well as staff members of the Southern Utilization Research and Development Division.

The presentations of the first day of the conference centered upon fiber properties and mechanical processing of cotton. Those of the second day were devoted to its chemical modification and finishing. In addition, a resumé of the wool research program of the Western Utilization Research and Development Division was presented.

WELCOME TO THE CONFERENCE

C. H. Fisher, Director
Southern Utilization Research and Development Division
New Orleans, Louisiana

On behalf of the Southern Division, I welcome you most cordially to this conference.

It has been our custom for many years to hold annual conferences, with limited attendance, with our official advisors to review our cotton research. This is the first time, however, that the Division has sponsored a general and open conference of this kind on cotton. As indicated by the program, wool research at our sister Western Division also will be reviewed. We are pleased because so many of you are sufficiently interested in our work to attend.

We thank you for deserting your busy desks or laboratories to participate in these discussions of cotton and wool research. We hope you will feel well rewarded when you return home.

At present there are about 150 scientists and technicians engaged in cotton utilization research at the Southern Division, with about 95 persons working in supporting roles. During this conference we shall report on the accomplishments of this group.

Although this conference was not arranged to commemorate the Twentieth Anniversary of the Southern Laboratory, I would like to point out that it was 20 years ago that a small group of scientists and engineers entered the new Southern Laboratory and embarked on a program of utilization research to aid cotton and other Southern crops.

The twenty-year existence of the Southern Laboratory has coincided with a period of phenomenal progress in the improved utilization of cotton and other farm products. During this period, research by many organizations has brought about a revolution in the cotton textile industries. We are proud of the part the Southern Division has had in bringing about this revolution.

Contributions of the Southern Division to cotton's cause may be divided into two types.

The first type, and the more important, consists of new basic and scientific information about cotton. This information is contained in about 1000 publications, including patents, that describe cotton research by the Southern Division. We believe this new information has been stimulating and exceedingly helpful to other organizations working for the benefit of cotton.

The second type of contribution to cotton's cause consists of the approximately thirty commercialized developments stemming from, or significantly aided by, research of the Southern Division. These include certain improved wash-wear formulations, flame resistant cottons, the cotton opener-cleaner, aerodynamic cleaner, granular card, improved processing guides, and better instruments for measuring and controlling cotton quality.

Most of the work of the Southern Division has been done in cooperation with others. We acknowledge with sincere gratitude this invaluable assistance.

Of the new developments from all cotton research of the Fifties, wash-wear cottons outrank the others in importance. The National Cotton Council estimates that this development is responsible for the sale of an additional 1,200,000 bales of cotton per year.

With the revolution of the Fifties behind us, there is good reason to believe that progress in cotton research and technology will be extended and even accelerated in the Sixties. We welcome the challenge of working cooperatively with you and others to achieve this end.

We are grateful to everyone contributing efforts to make this conference successful. I wish to thank Ralph M. Persell for early planning and E. Fred Pollard and his coworkers for handling arrangements and numerous details.

We are grateful to our official advisors for the valuable help given to us over the years and that to be given during this conference.

I wish to thank the several persons who have kindly consented to serve as chairmen. These include: M. Earl Heard, General Chairman; and Louis L. Jones, Jr.; George S. Buck, Jr.; C. Norris Rabold; and Lawrence L. Heffner, who are serving as chairmen of the various sessions.

Dr. Heard, our general chairman, is well known and admired throughout the textile industry with a distinguished record of service since he received degrees from the Georgia Institute of Technology and Texas Technological College. He served as Dean of the Philadelphia Textile Institute in the Forties and received the

honary degree of Doctor of Textile Science from this Institute in 1958. For some years he has been vice-president in charge of research at West Point Manufacturing Company.

He is a trustee of the Textile Research Institute and a member of many research organizations.

He has served with distinction in many important posts. Several years ago when President Eisenhower wanted a good man to head the Cotton Task Group, he selected Earl Heard. He carried out the duties of this post with credit to himself and benefit to the cotton industry. We are very fortunate to have him with us as leader of this conference. Dr. Heard.

FIRST SESSION

Chairman: Louis L. Jones, Jr.

IMPROVEMENT IN COTTON QUALITY THROUGH RESEARCH

Mason DuPré, Jr.
Assistant to Administrator
Agricultural Research Service
Washington, D. C.

Mr. Chairman, members of the Conference, I am very happy to be with you and to take part in this Conference.

I believe most of us have a full realization of the fact that more than ever before the key to cotton's future lies in further and further increasing the quality of cotton and of cotton products. Improvements in quality has not always been considered to be the key to cotton's future, but there were two developments in the late

1930's which foretold that this would soon be true. I am referring to nylon, the first truly synthetic, commercial textile fiber, and to high tenacity rayon, both of which were destined to become strong competitors of cotton with performance, or quality, rather than simply price, the major factor of competition. More important than these developments themselves, was that they were in effect a prophecy of many more such developments to come in the future--a whole host of new types of synthetic fibers with specialized properties, new kinds of plastics, new and improved paper products, and so on, all products of modern industrial research.

For simplicity's sake I am using the term "quality" in a broad sense as it refers to (1) raw cotton, and (2) finished cotton products for consumer use. By quality of raw cotton I am referring to those attributes that collectively determine its manufacturing performance and that have an affect on the quality of end-use products. By the quality of finished products I am referring to such elements as durability, comfort, wrinkle resistance and recovery from wrinkling, resistance to soiling, weather resistance, esthetic appearance, and so on.

Note: At this point Mr. DuPré digressed from the central theme of his talk to make a special statement regarding the quality of American cotton. The following is an excerpt from this statement:

We are meeting at a time when strong claims are being made in newspapers and trade publications, and at technical and trade association meetings and conferences, that the quality of American cotton has deteriorated and is continuing to deteriorate. Also, accusations and counter-accusations are being made that

practices by this or that segment of the industry is the, or a, major cause of the claimed deterioration. These claims and accusations apply mostly to the last fifteen years, and especially to the last ten.

Whether the quality of American cotton being delivered today to mills is of higher or lower quality than that of fifteen years ago is really somewhat beside the point, so far as research is concerned. The quality of most American cotton is good, as evidenced by the high quality of cotton products on the market today. But this, too, is beside the point and it is not a valid basis for believing that the quality is satisfactory. If the industry is not to suffer gradual attrition through losses of markets to its competitors, the quality must be substantially increased over what it is today, and commercially feasible methods and instruments for adequately measuring quality must be developed and put into use in the buying, selling, and use of cottons.

Up until the 1930's, the magnitude of the domestic consumption of cotton was influenced very little by quality per se, other than by those inherent, well-known qualities that cotton already possessed. By that I mean cotton was primarily a workhorse fiber--durable and low in cost--and consumption fluctuated closely with the general level of prosperity of the country. Moderate improvements in quality would have had little influence on consumption in these past years, although such few improvements as were made then are having an influence today. Exports depended mostly on price, as they do today. Cotton was cotton, wool was wool, silk was silk, and linen was linen. We produced certain qualities of cotton and we used these cottons.

Today, as everyone knows, cotton is not only a durable, comfortable fiber, but it has also taken its place in the textile industry as a quality fiber. People are willing and able to pay the price for textile products that give them the kind of performance they want. In this setting, cotton is in the very midst of ruthless,

severe competition where its competitors are spending literally scores of millions of dollars in research and development to capture textile markets, and where quality, or performance, is the Open Sesame of the future. A reasonable price is important, but required performance is a must.

The total effects of research conducted in the various segments of the cotton industry are complex. What quality of seed cotton the producer brings to the gin is the result of breeding and production research, and the quality of the seed cotton defines many of the technical problems of the ginner. What the ginner does about his technical problems is the basis of many of the technical problems that the manufacturer is faced with. But, starting at the other end of the pipeline, what the consumer wants in his textile products and will pay for determines what the manufacturer <u>must</u> supply, and what the manufacturer <u>can</u> supply in the form of cotton products depends upon both the quality of the cottons he has available and what qualities he can impart to his yarns and fabrics. Thus, as never before, technological developments in one segment of the industry frequently have a profound influence on the problems and economic well-being of the other segments.

Technological developments in the cotton industry within the last few years have brought with them many new problems that must be solved if the quality of cotton products is to be improved or even maintained. Nevertheless, there is no cause to regret the occurrence of the technological developments that have brought about these new

problems. Rather, almost all of them are typical of those that arise in many industries where progress has been rapid. And it is certainly true, measured by any standard, that the cotton industry is progressive and that technological progress has been rapid in all segments of the industry.

Today and tomorrow, you will hear and discuss reports on various phases of our utilization research on cotton. All of this research has the central aim of enhancing the competitive position of American cotton.

IMPROVED MECHANICAL PROCESSING

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Cotton accounted for only 4% of the world's apparel fiber consumption in 1800 (1); wool and flax being the chief fiber in use at that time. However, with the invention of the cotton gin in 1794 and the basic mechanical processes of the Industrial Revolution in textiles which took place in the latter half of the 18th century, cotton consumption increased rapidly from about 200,000 in 1800 to 20,000,000 bales in 1900 (1). Total world consumption last year is estimated at 48.2 million bales (2), an alltime high, and world production this year (1960-61) is estimated at 47.5 million bales.

It is encouraging to note from Figure 1 that the rate increase in

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Figure 1. World Mill Consumption of Commercial Cotton, 1920 to Date

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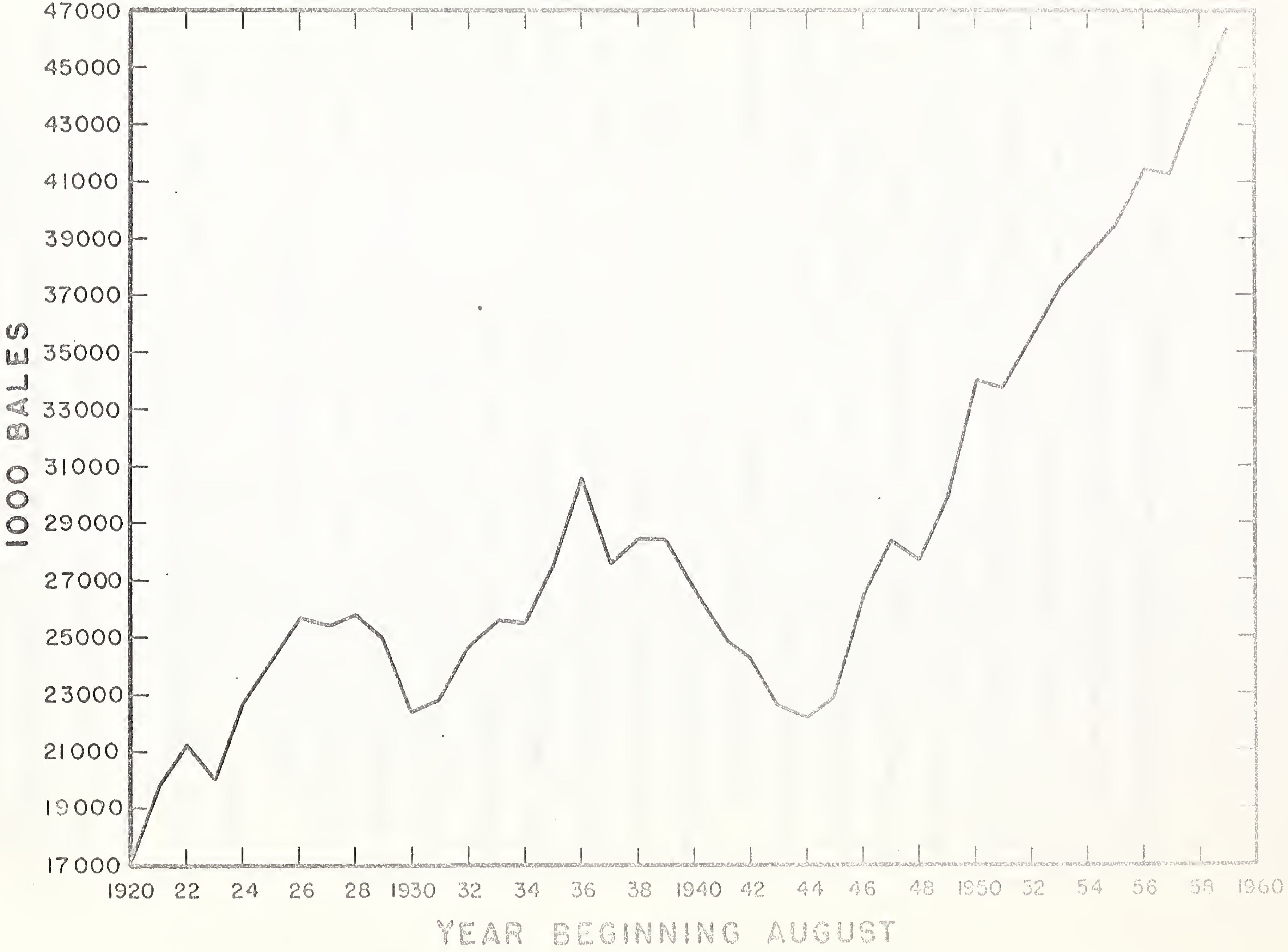
- 7 -

Figure 1.

WORLD MILL CONSUMPTION OF COMMERCIAL COTTON, 1920 TO DATE



world consumption of cotton has been much greater during the past 15-year period than it was in the previous 25-year period (3), and this, no doubt, has been due principally to the explosion in population and increased standards of living of the people of Asia and Africa and to the efforts to expand cotton consumption in this country and in Europe.

After this rather sketchy outline of the evolution of the cotton industry and of cotton usage on a world basis, I would like to consider with you the factors that affect cotton consumption today. Cotton is used almost wholly in the form of woven or knitted fabrics, and the degree to which these cotton products meet consumer requirements will exert a major influence on cotton consumption. The relative price of cotton and competing fibers, and the ease with which cotton and these competing fibers can be processed will affect which fibers textile mills will choose to process.

Comprehensive market research studies, conducted by the National Cotton Council of America, have shown that quality, price, and sales promotion directly or indirectly influence textile consumption and the consumption of individual textile fibers (4). They concluded that the greatest opportunity to maintain cotton's markets, and to expand cotton consumption is through research to improve quality and reduce costs and prices. A better position in quality and price with respect to competing materials will also strengthen the basis for sales promotion activities. The price at which domestic cotton growers can

profitably grow cotton will be an important factor in determining how successfully our domestic cottons will compete with man-made fibers and with foreign growth cottons in world markets. Since the quality of cotton products also significantly affects the overall competitive position of cotton with man-made fibers, cotton growers can best help cotton maintain its present dominant world position by growing cottons having those properties which will best meet processing and consumer requirements at the lowest possible costs, and cotton spinners can contribute by producing cotton products of maximum quality at the lowest possible prices.

Since the quality of cotton products and the efficiency at which available cottons can be spun and woven is dependent in large measure on the properties of these cottons, it is pertinent to examine the trends that have taken place in fiber properties during the period for which information is available. Figure 2 shows that begining with

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Figure 2. Percent Production of American Upland Cotton by Staple Length, United States for Specified Periods, 1928-29 through 1959-60 Crop Years

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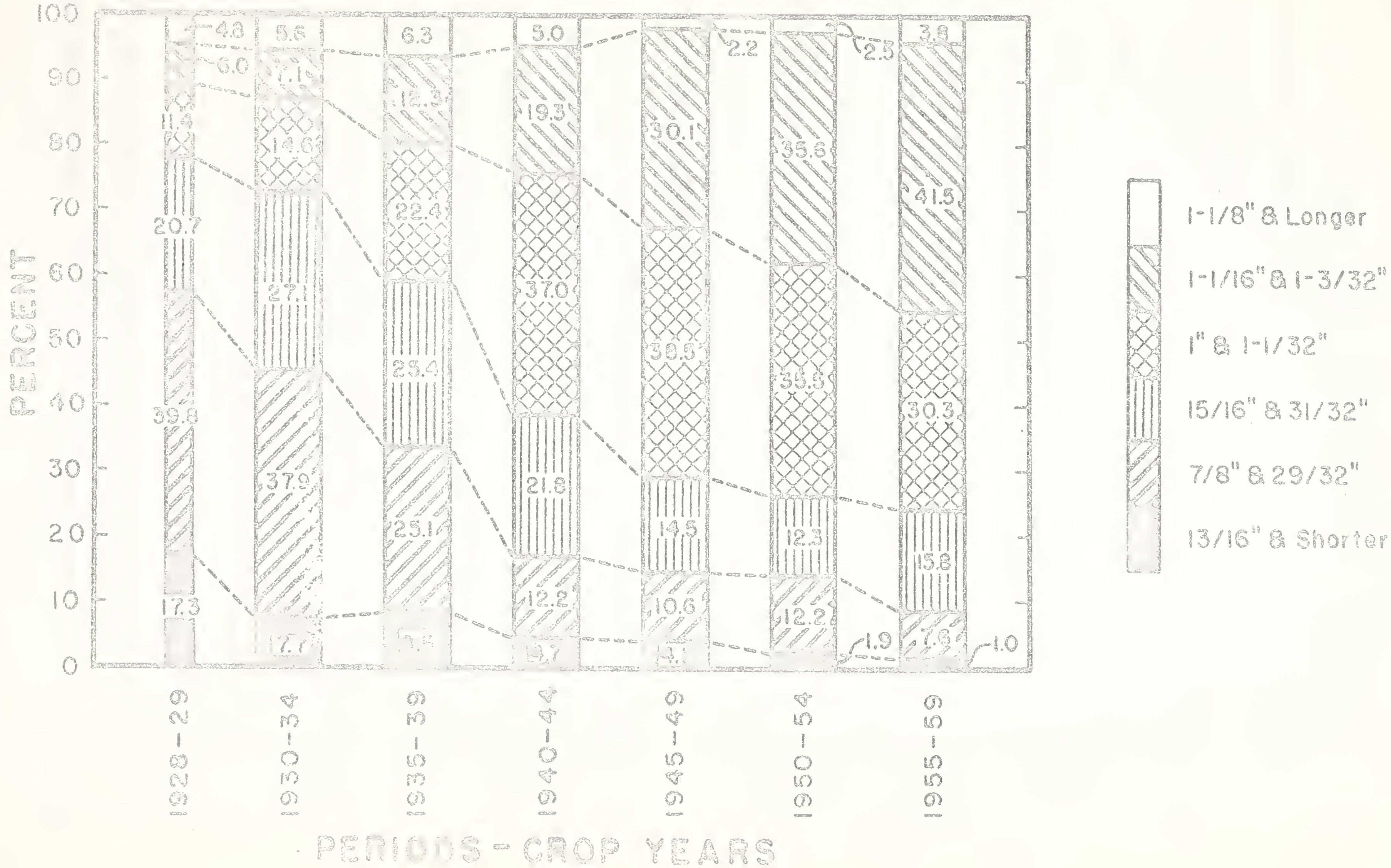
the crop of 1928-29 (the first year that we have official estimates on staple length) there has been a significant improvement in the length of our Upland cottons. You will observe that during the period from August 1, 1928, through July 31, 1930, 57% of the crop was 29/32" and shorter, whereas by the period 1955-60 these lengths represented less than 9% of the crop. I particularly want to call your attention

Figure 2.
PERCENT PRODUCTION OF AMERICAN UPLAND COTTON BY STAPLE LENGTH, UNITED STATES FOR SPECIFIED PERIODS, 1928-29 THROUGH 1959-60 CROP YEARS



to the increases in percentages of our "bread and butter" cottons, that is, the 1" to 1-1/32" and 1-1/16" to 1-3/32" length groups. These two length groups represented only slightly over 17% of the 1928-30 crops, whereas by 1955-60 they represented over 71% (3).

Mr. George S. Buck, Jr., National Cotton Council of America, has recently made an analysis of the data contained in the USDA's cotton quality surveys of the cotton crops for the period 1946 to 1959 (5). He concluded that the following changes had occurred during this period:

> "Five percent increase in strength, a one-third drop in non-lint content, no deterioration in color, and nearly constant length.
>
> "Cottons have become a little finer, but are in the desirable range. Until recently the trend in length uniformity was upward.
>
> "This means our cottons have not gone to pot. In some ways they are getting better.
>
> "In other respects, however, there is room for concern. In the past 15 years yarn appearance index has trended steadily downward. While at least a part of this can be explained by shifts in varieties, some of the trouble might be due to changing technologies of harvesting and ginning.
>
> "Another distrubing indication is the decline in the fiber length uniformity and yarn strength the past four years."

The USDA's Agricultural Marketing Service Reports of "Cotton Fiber and Processing Test Results" for the crop of 1960-61 included both Suter-Webb and Digital Fibrograph measurements of fibers shorter than 1/2". The relationship between the two measurements is not very good.

However, an analysis of the Suter-Webb data shows that about 85% of the samples of cotton contained in the survey fall into what mills find is a reasonable range of short fiber content of 14% and under. Some of the cotton, however, contained 20-24% by weight of fibers less than 1/2" in length. Our investigations of the effect of short fibers of varying percentages have conclusively shown that cottons containing such high short fiber content of fibers shorter than 1/2" for cottons within the staple length group 1-1/16" significantly affect end breakage during the spinning of print cloth yarn numbers (30/1 warp and 40/1 filling yarns), particularly for mills which are spinning at eleven to thirteen thousand rpm spindle speeds. Our studies, also, showed that increases in short fibers detrimentally affected yarn uniformity and fabric appearance.

The radical change from hand picking cotton and drying it in the field, to mechanical harvesting, where the seed cotton goes directly to the gin, has introduced a number of problems with respect to spinning performance and the quality of fabrics produced. The moisture content of machine-harvested cotton is generally too high to permit ginning without serious fiber damage. This has resulted largely in the installation of seed cotton dryers at gins and, since the machine-harvested cotton also contains more trash than hand-picked cotton, the installation of seed cotton cleaners and lint cleaners. The mechanical working of cotton fibers at low moisture contents has led to excessive fiber breakage and a reduction in spinning performance. Furthermore, if the cotton is dried to too low moisture content at the gin and does

not regain sufficient moisture before it is processed at textile mills, the mechanical working of the embrittled fibers will cause further excessive fiber breakage.

Before passing on to a discussion of technological problems which changes in harvesting and ginning practices have created, it is pertinent to mention that the Agricultural Experiment Stations in the cotton growing states and the U. S. Department of Agriculture, in cooperation with various segments of the cotton industry, have developed coordinated research programs designed to improve the competitive position of American growths through (1) the development of cotton strains of improved fiber properties and higher yields; (2) better farming practices, including mechanized tillage and harvesting; (3) insect and disease controls; (4) improved ginning practices; and (5) research to maintain present and find new uses for cotton. The program of cotton utilization research is conducted in five of the Laboratories of this Division, i.e., Cotton Physical Properties, Cotton Chemical Reaction, Cotton Finishes, Cotton Mechanical, and Engineering and Development Laboratories.

Since my discussion is specifically concerned with improved mechanical processing as a means of improving the competitive position of cotton and increasing its consumption through improvement in product quality and lower processing costs, I will limit my remarks to the research conducted in our Cotton Mechanical Laboratory. This Laboratory consists of: Machinery Development, Processing Efficiency, and Fabric Design Investigations.

The Machinery Development Investigations are concerned with the development of radically new types of processing machinery and methods for improving quality and lowering costs. Since Mr. Ralph A. Rusca, who leads this group, will review recent developments in this area, I will merely say that the results obtained have fully justified our original concept that this was and is a fertile field in which to work. The developments have significantly contributed to maintaining cotton consumption through improvements in quality and the lowering of costs of cotton products.

The Processing Efficiency Investigations, headed by Mr. Louis A. Fiori, are concerned with the determination of the effect of fiber properties on yarn and fabric properties and processing efficiency; determination of the effect of yarn and fabric structure on fabric properties and their serviceability; development of engineering concepts for functionally relating cotton fiber properties to yarn and fabric properties to obtain maximum utilization of fiber properties, and the development of basic information on processing principles from which to formulate procedures for successfully processing natural and chemically modified cotton fibers. Messrs. Fiori and Tallant of this Investigation will discuss the results obtained in our "blending" and "short fiber" investigations, which will give detailed information on some of the research being conducted in this area. Other examples of the contribution made by this group are a better understanding of the effect that fiber fineness, length, strength, and elongation have on yarn properties and processing efficiency (6); the development of new

roving twist formulas and easy-to-use nomographs for carded and combed cotton rovings have contributed substantially to improvements in product quality and processing efficiency (7); the development of new draft guides for long draft roving frames, also, have contributed significantly to improvements in the uniformity and strength of cotton yarns (8).

The Fabric Design Investigations, led by Mr. John J. Brown, are concerned with the determination of the physical and other requirements of selected end-uses for cotton; the design and development of new and improved cotton fabrics from untreated and chemically modified cotton to meet the requirements of selected end-uses, and the determination of principles of fabric geometry and relation of these to fabric properties and performance, and the mechanism of fabric phenomena involving yarn movements. This group has recently developed a high stretch cotton yarn which looks very promising for obtaining desired resilience in woven fabrics and an increase in fabric loftiness and improved thermal properties. Other examples of developments are stronger cotton tire cords; a light-weight steep twill cotton fabric having good cover but very permeable to the passage of air, which has been adopted by the Navy Department for their summer flight uniforms; high density fabric for rainwear; a high density cotton sateen for use in cold-wet combat uniforms which is now being service tested at the Army's combat course, Fort Lee, Virginia.

In conclusion, I would like to emphasize that changes in mill processing techniques, such as increase spindle speeds and the use of

larger packages, have resulted in increased stresses being placed on yarns during spinning. And this, coupled with changes in fiber properties caused by recent changes in cultural, harvesting and ginning practices have magnified the problems of efficiently processing our cotton into quality products. Furthermore, the elimination of a number of prespinning processes have greatly reduced the number of doublings and the opportunity for blending. These have further emphasized the need for additional information on the effect that fiber properties and processing variables have on spinning performance and product quality. Some of the immediate problems that need to be solved are (1) the development of precise and rapid methods for measuring physical properties of cotton fibers, particularly length distribution (short fibers) so that presently available cottons can be selected and blended in the proportions required to yield optimum processing efficiency and product quality; (2) more precise information on the interrelationship between fineness and length with respect to their combined effects on spinning efficiency. For example, when the cotton crop is particularly coarse, what additional length is required to obtain the same spinning efficiency as previously was obtained with finer cotton; (3) better means of removing trash from cotton with less fiber breakage, including removal of the fiber length, which do not contribute to yarn uniformity and strength, and hence, decrease spinning performance; and (4) investigations designed to obtain optimum utilization of presently available cottons of different fiber properties through adapting processing methods and requirements and selection of cottons for specific end products for which their fiber properties are especially suitable.

Although cotton textile machines and methods for processing cotton have been significantly improved during the past 50 years, modern textile mills still use about 15 different processes in manufacturing cotton into fabric form as compared with the continuous systems used in manufacturing paper and plastics, requiring an excessive amount of labor. I concur fully with my colleague, Mr. Rusca (9), that radically new methods for processing cotton into textiles are needed to meet the mounting competition cotton is meeting from plastics, paper, nonwovens, and continuous filament man-made fibers which require fewer stages in processing than do staple fibers. Research to solve this problem would require large sums to do the basic work and still larger sums to develop the necessary processing equipment. However, the large savings that would accrue would seem to amply justify the expenditures. It was heartening to read recently that a large textile corporation is planning to use the latest research information in building as nearly an automated textile processing plant as our present knowledge will permit.

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RECENT ADVANCES IN TEXTILE PROCESSING MACHINERY

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An important part of the research program of the U.S. Department of Agriculture to increase the utilization of cotton is the development of new and improved textile processing equipment and methods to raise

the quality and lower the cost of cotton products. The Department's machinery research is centered at the Southern Regional Research Laboratory, New Orleans. Both fundamental and applied studies are conducted. A large part of the research is concerned with the development of improved textile equipment for cleaning and carding cotton. This paper will report some of the Laboratory's more recent accomplishments in these and associated fields.

Integrated Cleaning System

Several years ago, research was initiated to develop a system for cleaning cotton at the mills wherein the function of each machine in the system is integrated and synchronized with every other machine (1). By this approach it was believed that more effective cleaning could be achieved without fiber damage. The proposed system evolved to the present concept of a Bale-Breaker-Blender that opens and blends cotton in any desired proportion from up to 20 bales, an Opener-Cleaner with an integral Aerodynamic Cleaner that provides an overall trash removal efficiency of 35-45% at 1,500 lbs./hr. production, and a Carding Cleaner type finisher picker that removed 40-50% of the remaining trash at 400 lbs./hr. production. The Bale-Breaker is under development; the latter two machines are available commercially and will be discussed briefly.

Opener-Cleaner

The SRRL Opener-Cleaner (2) is the well-known SRRL Opener (3) with built-in cleaning mechanisms. The Cleaner retains the opening and blending ability of the Opener and, in addition, subjects the

cotton to cleaning while the cotton is in a very open condition. Figure 1 is a diagram of the Opener-Cleaner equipped with the new SRRL

Figure 1. Schematic Diagram of Opener-Cleaner with Aerodynamic Cleaning Attachment

Aerodynamic Cleaner (4). The machine has four wire-wound processing cylinders (A) with special forwardly-inclined teeth, and one cylinder (B) with rearwardly-inclined teeth. Cylinders (C) remove the small tufts of loosely held cotton from cylinders (A) and clean the cotton by means of a pair of combing cylinders (D) used in combination with textile-type grid bars (E) applied in an unconventional manner.

The doffing system utilizes soft revolving strip brushes (F) which remove the cotton from the cleaning cylinders and at the same time serve as centrifugal fans (5). The process of doffing the cotton from the cleaning cylinders results in further opening and loosening of the trash. The cotton is carried by air currents through specially shaped ducts that spread out the cotton into a wide, thin sheet. At point (G) the cotton changes direction abruptly under the influence of suction from a conventional condenser; motes and trash are ejected into waste box (H) while the cotton goes into ducts (I) and then to the condenser.

Evaluations of the Opener-Cleaner without the aerodynamic attachment indicate that the machine removes an average of about one-third of the trash in cotton, depending upon the type of cotton and trash,

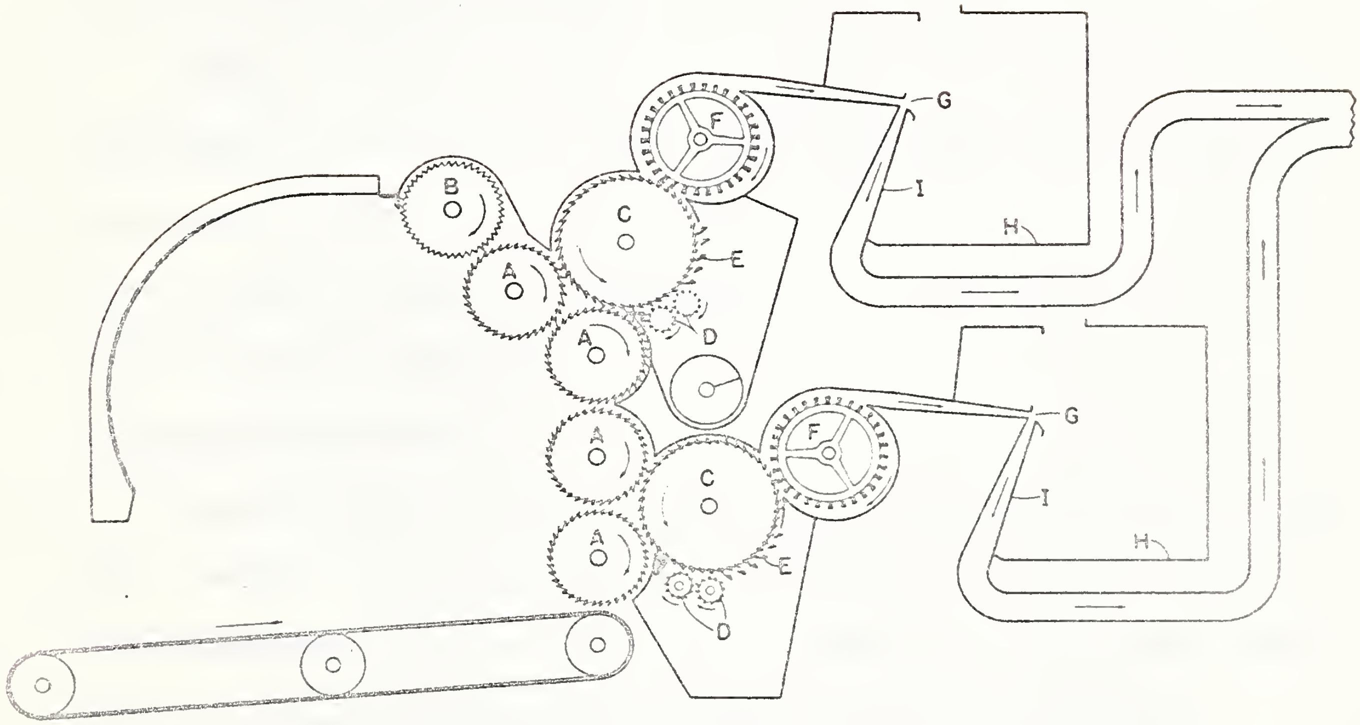

Figure 1. Schematic Diagram of Opener-Cleaner with Aerodynamic Cleaning Attachment

at a production rate of 1,500 lbs./hr. (Table I). These results

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Table I. Effect of Opener-Cleaner on Cleaning Efficiency and Waste

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are confirmed by mill experience.

Addition of the air-type cleaner increases the overall cleaning efficiency of the machine by about one-third without increasing the percentage of fiber in the waste. Mill evaluations of the combined Opener-Cleaner Aerodynamic Cleaner are not yet available due to the recency of this development.

Carding-Cleaner Picker

The final unit in the cleaning system is the SRRL Carding-Cleaner (6). Designed as a modification for standard cotton textile pickers, this development increases the cleaning efficiency of the picker about 400%. A schematic diagram of the machine is shown in Figure 2.

Figure 2. Schematic Diagram of Carding-Cleaner Picker

Essentially, the picker conversion consists of replacing the blade or Kirschner beater with a wire-wound cylinder (A). The pedal evener motion is replaced with a wire-wound "antipluck" feed roll (B). The feed roll is unique in that the wire is wound into two spiral grooves so that the teeth in one groove point in the opposite direction to the teeth in the other groove. The forwardly-inclined teeth advance the cotton from the blending reserve delivery to the carding-beater cylinder. As the carding-beater strips the feed roll, the cotton is combed across

Table I. Effect of Opener-Cleaner on Cleaning Efficiency and Waste[1/]

Quality of Cotton	Cleaning Efficiency, %	Waste Removed, %	Trash in Waste, [2/] %	Fiber in Waste %
M grassy, 1-1/16 in.	23.8	0.94	76.7	23.3
M, 1-1/4 in.	31.7	1.11	85.9	14.1
LM, 1-1/6 in.	25.0	2.13	89.4	10.6
LM, 1-1/32 in.	34.1	2.19	85.2	14.8
SGO, 31/32 in.	37.9	4.22	88.4	11.6
SGO, 1-1/32 in.	43.2	4.37	88.1	11.9

$$\text{Cleaning efficiency} = \frac{\text{trash in cotton fed} - \text{trash in cotton delivered}}{\text{trash in cotton fed}}$$

1/ Determined with a Shirley Analyzer.

2/ Includes invisible loss.

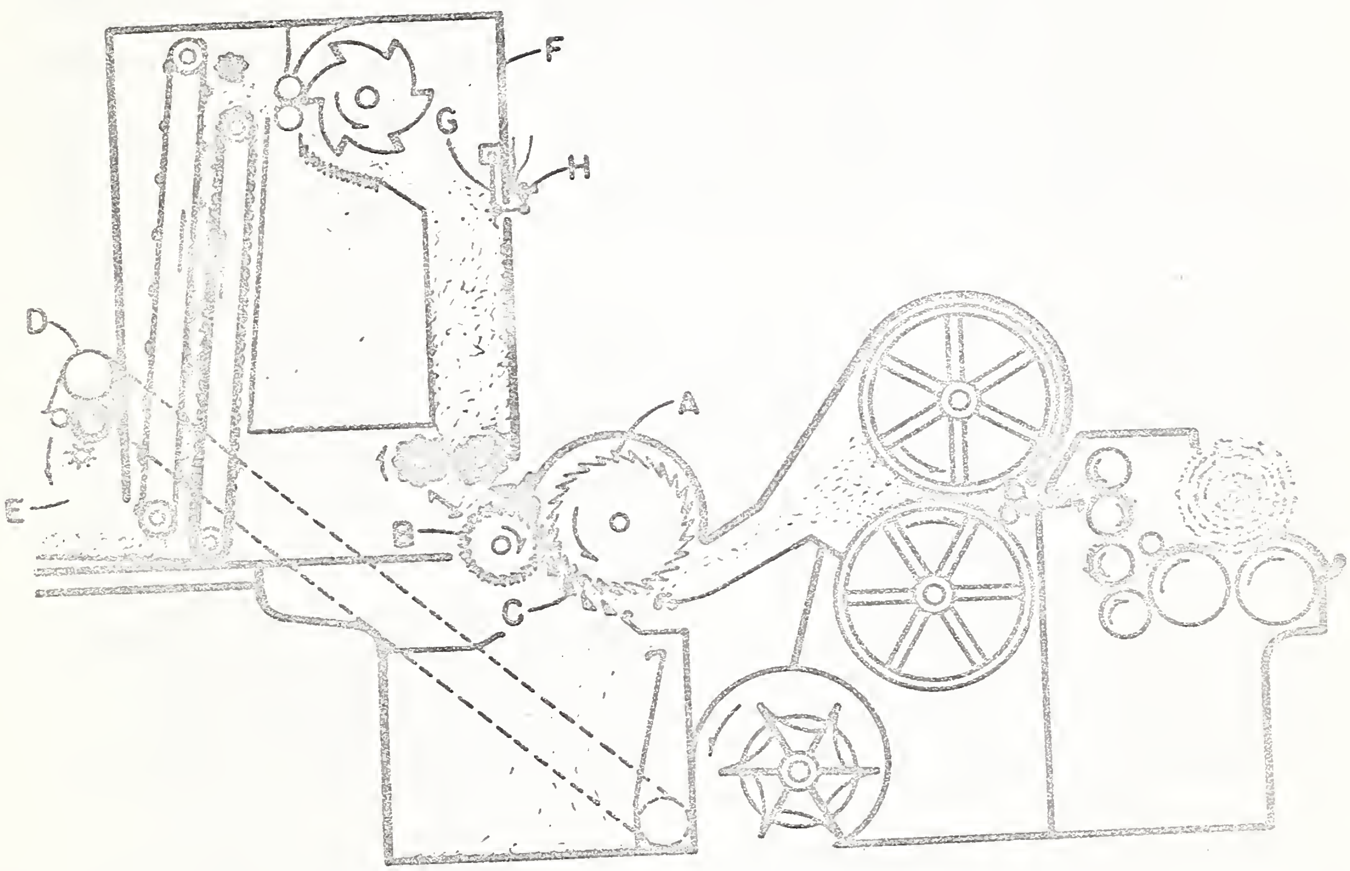

Figure 2. Schematic Diagram of Carding Cleaner Picker

the backwardly-inclined teeth and is thoroughly opened. The cotton is then cleaned by a set of four triangular grid bars (C). Lint loss through the grids is minimized by a simple lint recovery system (D) which draws a slight stream of air across the top of the trash box to catch the falling fibers. The recovered fibers are deposited on the incoming cotton (E) for reprocessing, or the fibers may be collected separately.

Two changes are made to improve the feed system. The belt-shifting mechanism controlling the feed to the blending reserve (F) is replaced with a fast-acting pneumatic clutch (7) and the rake-type control in the blending chute is replaced with a light aluminum gate (G) directly coupled to a mercury switch (H).

The cleaning efficiency of the Carding-Cleaner alone is presented in Table II. This machine takes out an average of 45% of the trash

Table II. Waste Removal by the Carding Cleaner Unit

remaining in the cotton after the cotton has been processed through the hopper, breaker-picker, and blending reserve.

Evaluation of the Opener-Cleaner, Carding-Cleaner integrated system with a limited number of cotton indicates that the two machines will remove from 70% to 80% of the foreign matter. The waste averages about 85% trash and 15% fiber, with approximately 60% of this fiber being shorter than 1/2 in. in length.

Table II. Waste Removal by the Carding Cleaner Unit

Variety of Cotton	Cleaning Efficiency,1/ %	Waste Removed, %	Lint in Waste,1/ %
Acala 4-42	45.2	1.18	9.8
Paymaster	39.5	0.77	11.4
Deltapine 15	49.9	1.44	13.1
Average	44.9	1.13	11.4

1/ Determined with a Shirley Analyzer.

Granular Card

Concurrent with research on cleaning equipment, investigations were conducted to improve the quality of sliver and reduce the waste from the cotton textile card. Extensive aerodynamic studies (8) revealed that carding is accomplished through mechanical action and not through air action. Further studies led to the conclusion that the essential requirement for carding is that the tufts and unopened groups of fibers deposited on the cylinder by the lickerin encounter a resistive force sufficient to separate and spread the fibers over the entire area of the cylinder surface before reaching the doffer. Based on these principles, the SRRL Granular Card was developed (9).

The Granular Card is a standard flat top card converted to carding without flats. The flat assembly and flexible bends are replaced with an air-tight cover with an aluminum oxide carding surface closely spaced to the main cylinder, and a small metallic wire roll is installed in conjunction with the lickerin to preopen the fiber tufts thoroughly before carding. Although not required for carding without flats, the use of a modified lickerin cover that improves cleaning at the mote knives is recommended.

The general design of the Granular Card is shown in Figure 3,

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Figure 3. Pictorial Diagram of the Granular Card

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wherein lap (A) is fed under the new-type lickerin cover (B) to the lickerin (C) which deposits the fibers on main cylinder (D) in the

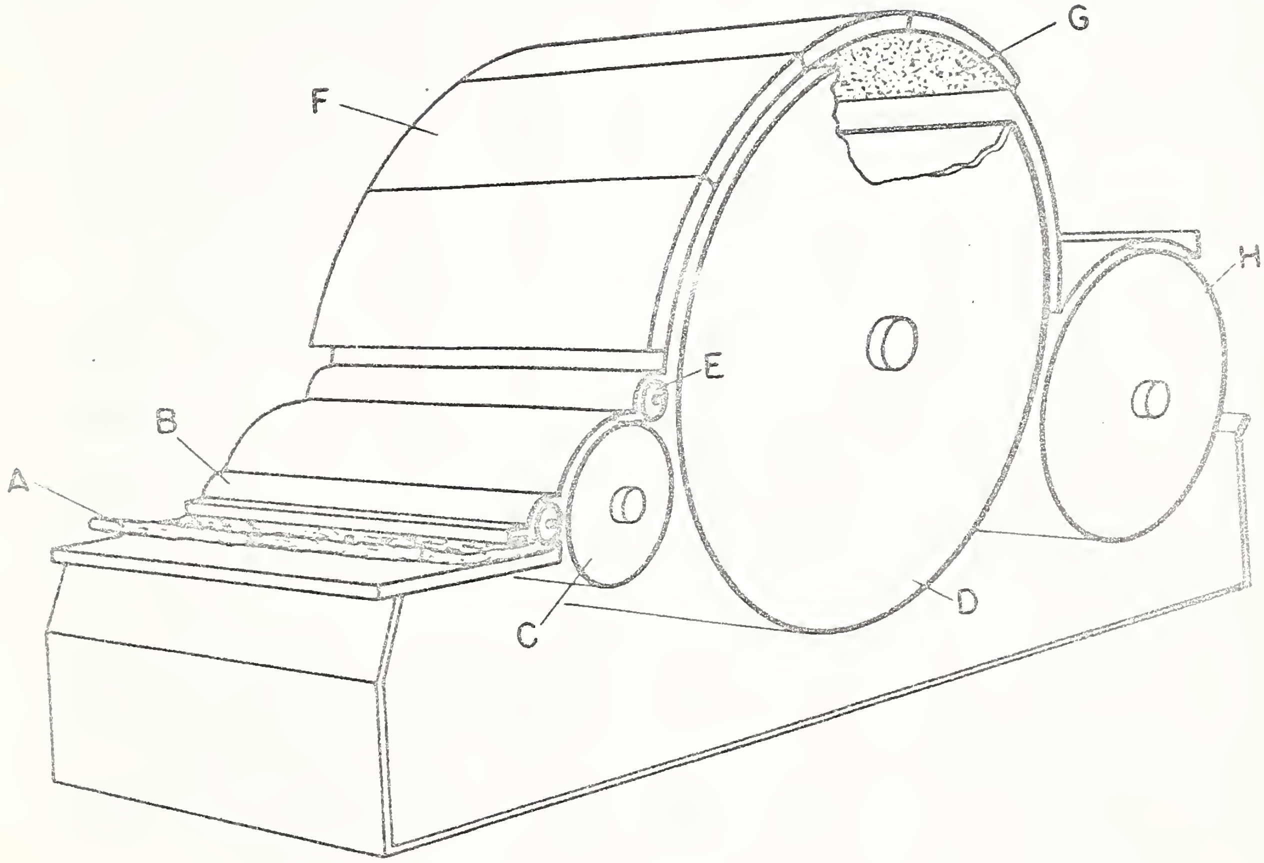

Figure 3. Pictorial Diagram of the Granular Card

conventional manner. Large tufts or groups of fibers are combed from the main cylinder by preopener roll (E), which returns these tufts to the the lickerin for reprocessing. The fibers on the cylinder (D) are subjected to a carding action by the granular surface (G) on the underside of stationary cover (F). Doffing is accomplished by the usual doffer cylinder (H) and comb mechanism.

Technical details of the Granular Card were made available to the textile industry in April 1959. To date, 22 textile machinery manufacturers are licensed under USDA patents to produce the card, and about 65 mills have experimental installations of one to five cards. Figure 4 is a photograph of a Granular Card in a cotton mill, and

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Figure 4. Photograph of Granular Card in Cotton Mill

Table III presents mill results (10).

Table III. Comparison of Standard Card and Granular Card in Mill

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This new method of carding should lower processing costs. The customary 2-3% flat waste is eliminated, dust and fly are practically eliminated, card weight is reduced about 800 pounds, power requirement is reduced by 1/8 hp, and product quality remains about the same. There is a slight decrease in neps in the web and the possibility of a slight decrease in yarn appearance grade.

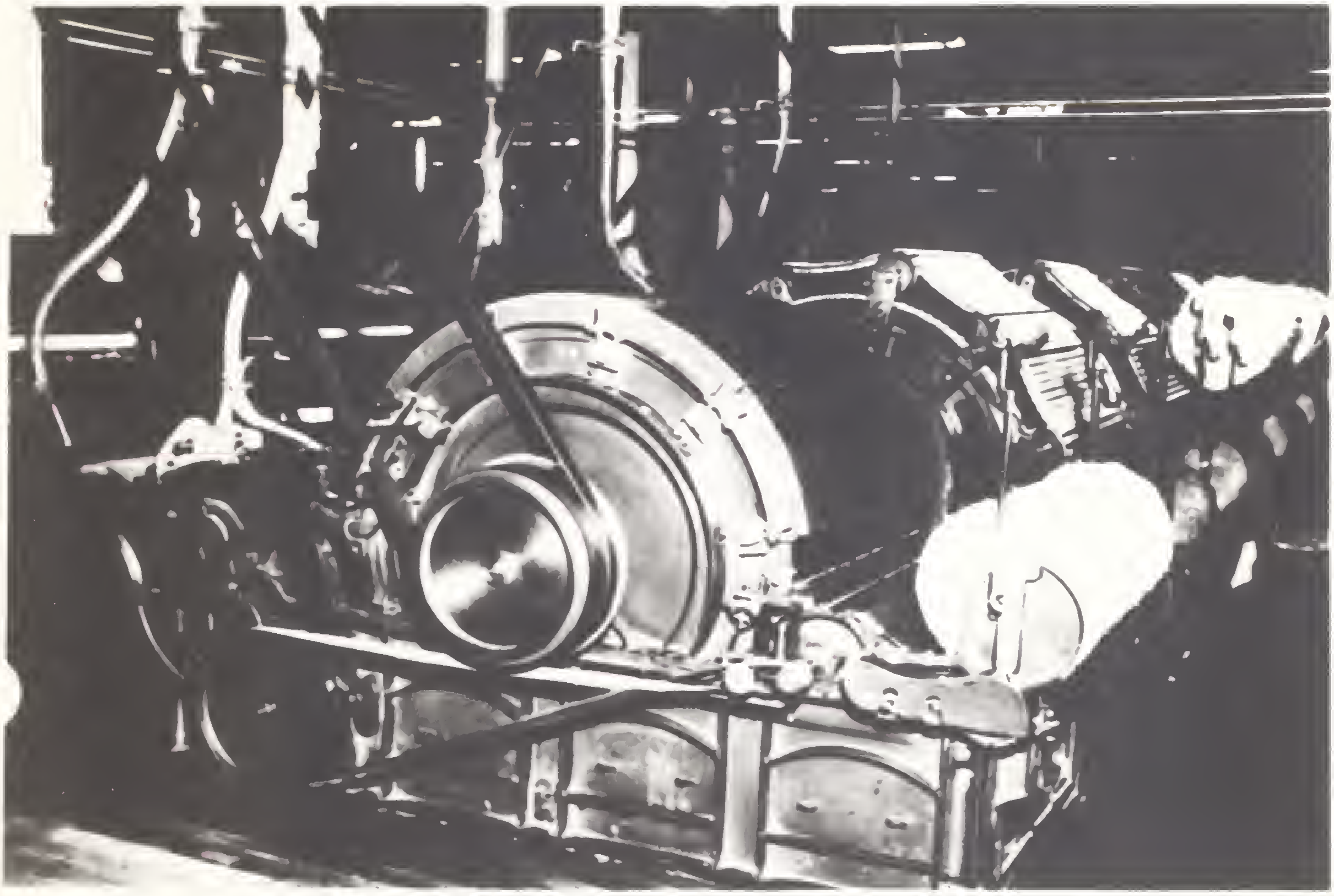

Figure 4. Photograph of Granular Card in Cotton Mill

Table III. Comparison of Standard Card and Granular Card in Mill

Product	Standard Card 1/		Granular Card 1/	
Waste,%				
Flat strips	2.02		0.00	
C & D strips	1.00		1.00	
Motes & fly	1.03		.71	
Total	4.05		1.71	
Waste Analysis, %	Lint	Trash	Lint	Trash
Flat strips	86.0	14.0	-	-
C & D	84.0	16.0	82.0	18.0
Motes & fly	34.2	65.8	20.6	79.4
Yarn Quality, 30/1 (19.7 Tex)				
Grade	C-		C	
Strength	Same		Same	

1/ Fillet wire

Determining Trash Content

One of the needs of the cotton industry is a rapid and accurate method of determining the foreign matter content of lint cotton. The standard machine (Shirley Analyzer) used for this purpose has a production rate of 2 to 4 pounds per hour and requires about 15 minutes to test a single specimen, or about one hour to evaluate a sample in accordance with ASTM procedure (11).

In the fall of 1959 research was undertaken to develop a practical method of determining trash content. The principle of the SRRL Carding Cleaner was incorporated into a laboratory size machine, designed in a manner to subject the cotton to multiple cleaning actions. Preliminary evaluations indicate the unit removes about 95% of the foreign matter at a production rate of 30 pounds per hour. On this basis, a bale of cotton could be analyzed for trash content in less than five minutes. Results appear promising, and it is anticipated that a final model will be developed by the end of the year.

Yarn Spinning Apparatus

The standard ring frame for spinning cotton yarns has certain mechanical features that limit yarn production rate, uniformity, and package size. In recent years improvements in rings and travelers have materially increased production rates, however, there has been no change in the ring diameter that restricts the size of the yarn package (bobbin) that can be spun.

Exploratory research has been completed on an original idea for spinning without the conventional ring and traveler (12). An experimental

model has been developed that has produced a high-twist medium-coarse yarn at rates equal to those of standard machines. The principle of the apparatus is shown in Figure 5. The model demonstrated the

Figure 5. Pictorial Diagram of Yarn Spinning Apparatus

possibility of producing yarn packages of almost unlimited size and shape by enabling the usual separate winding process to be incorporated into the spinning machine. Direct labor costs for winding would be materially reduced. Results of the research are being published so that industry can develop a prototype machine to evaluate the mechanical and economic potential of this new spinning method.

Summary

The need for higher quality, lower cost cotton products has stimulated research to develop improved cotton textile processing equipment. Recent machinery developments of the Southern Regional Research Laboratory include the Opener-Cleaner, Aerodynamic Cleaner, Carding Cleaner Picker, and the Granular Card, all of which are now commercially manufactured. Promising new developments include an apparatus for rapidly determining the trash content of lint cotton, and an experimental device for spinning yarn without the use of ring or traveler.

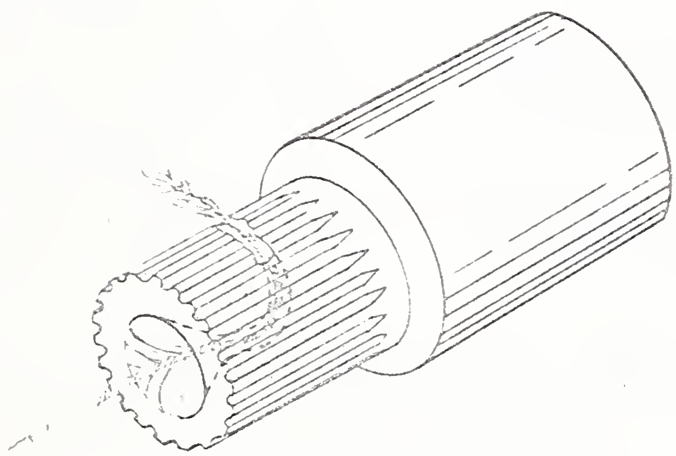

Figure 5. Pictorial Diagram of Yarn Spinning Apparatus

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MICROSCOPICAL OBSERVATION OF FIBER DAMAGE IN COTTON

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There are various kinds of damage which cotton may suffer in mechanical processing, finishing, and use. It is difficult, if not impossible to determine in the damaged sample of yarn or fabric the exact cause of the deterioration. However, from laboratory experiments in which undamaged samples have been compared with those known to have been subjected to certain damaging environments, a body of empirical information has been built up which is extremely useful in investigations of the condition of cotton materials. Microscopical evaluations, quickly arrived at, can be followed by the more conventional and lengthier analytical procedures for precise diagnosis of the source of deterioration. In these studies cotton fiber has been examined following controlled exposure to heat (7), high energy radiation (9), acid hydrolysis (4), microbial attack (8), and mechanical wear or abrasion.

Fiber Structure

Classical investigations with the light microscope have demonstrated that the natural architectural arrangement of the cotton fiber is that of concentric layers of cellulose encased in a skin of primary wall

containing noncellulosic substances of waxy, pectic, and nitrogenous nature (3), (10). Beneath the primary wall are many concentric layers of cellulose which constitute the secondary wall or main body of the fiber. The first of these, called the "winding layer" differs in structure from either primary wall or the rest of the secondary wall, but is a transition layer between the two.

Studies made with the electron microscope have revealed that the cellulosic portion of the primary wall is a network of fibrils interlaced in a sort of fabric in which the general system of orientation is axial on the outer surface and transverse on the inner face (13).

In electron micrographs, fragments of the many-layered main body of the secondary wall show an entirely different pattern of fibril arrangement from the primary wall; microfibrils are closely appressed in a strongly parallel system which appears continuous. These concentric layers are of varying thickness, but their average cross section is about 0.1 micron. There are from 25 to 40 layers in a normally developed fiber.

Light Microscopy

The encasing skin or primary wall is somewhat resistant to wetting, and to the passage of reagents to the interior of the fiber so that any break in the primary wall considerably alters the properties of the fiber, especially its response to swelling agents. The main microscopic tests for damage to cotton fibers, therefore, are based on the detection of any ruptures in the primary wall. This can be demonstrated by (1) staining of the primary wall, (2) staining of the secondary wall, and (3) by the behavior of the fiber on swelling in various reagents.

Staining and Swelling Tests. Because of the presence of the noncellulosic materials in the primary wall, it may be colored with stains for pectic materials or for fats; at appropriate magnifications breaks in the wall are readily detected where the uncolored secondary wall shows through. To emphasize these ragged places, swelling in sodium hydroxide solutions in concentrations of from 10 - 20% up may be useful.

Staining of the secondary wall is achieved by the use of substantive dyes such as Congo red or benzopurpurine which have a particularly great affinity for cellulose. They will stain very darkly any area where the protective primary wall is broken so that the dye solution may penetrate. If the fiber is dyed in a hot solution of the dye, then rinsed of all excess dye and placed in a solution of sodium hydroxide of mercerizing strength, the fiber will swell, rupturing the weak places in the primary wall. Any break which existed prior to dyeing will be red; any new break will be white. Thus one may judge the extent of initial damage and the position of weak places ruptured by the subsequent swelling.

The classical test for fiber damage is the Congo red test of Clegg (2). In the unswollen state cellulose fibers are colored a faint pink by aqueous solution of this dye. To improve the rate of dye absorption and depth of shade, the fibers are first swelled in 9% sodium hydroxide. They are then soaked in a 2% solution of Congo red, washed free of excess dye, and mounted in 18% sodium hydroxide for observation. Great swelling occurs and the primary wall ruptures further, exposing dark red irregular areas where the cellulose had been damaged prior to dyeing.. The stained areas indicate microbial, hydrolytic, oxidative, or mechanical damage.

A useful test based on differential absorption rates of two dyes of different size and shape is the Simons stain (6) used in the testing of paper pulps. The more absorptive areas of the fiber (thin immature fibers, bruised cellulose, greatly swollen cellulose) stain orange. Undamaged areas (less absorptive) stain dark blue shading into green toward the damaged, orange-dyeing areas. A modification of the Simons stain used in this laboratory involves a preswelling step and heating of the specimen in the dye.

Perhaps the most useful microscopical technique for the study of cotton is the pattern of behavior the fiber exhibits as it swells to solution in cellulose dispersing agents such as sulfuric acid, cuprammonium hydroxide, trimethyl benzyl ammonium hydroxide, and cupriethylenediamine hydroxide. Untreated fibers, immersed in a drop of the appropriate solution on a slide untwist with violent motion. A high degree of swelling occurs in the cellulose of the secondary wall, but the primary wall, which has a different structure and composition, does not expand, and, as a result of the pressure by the rapidly swelling secondary wall, is ruptrued in many places. The parts of the primary wall between the ruptures are pushed together to form rings; between the neighboring rings the secondary wall protrudes in the form of round balloons. If the cotton has been damaged in any way, the swelling is more irregular, and balloons may not form, or their shapes may be more elongated, so that the swelling

fiber resembles not so much a string of pearls as of link sausages. In material which has been thoroughly bleached, no balloons form, but swelling is more or less uniform along the entire length of the fiber. In cases of severe damage, ballooning may be completely lacking, and the fiber may go quickly into solution without any characteristic pattern of swelling. Comparison of the damaged fiber with control samples known to be normal in swelling response, makes the observations more meaningful.

A practical application of the swelling of cotton in mercerizing strength sodium hydroxide is the extrusion test (12), used in cases where numerical values are needed for comparison of several samples in a series. This test is performed by cutting the cotton samples into lengths of approximately one millimeter and immersing small amounts of this short fiber in 18% sodium hydroxide on a slide for one minute. The primary wall restricts the swelling of the fiber, and pressure developed inside the fiber causes the cellulose of the secondary wall to be extruded at the cut ends of the short fiber lengths which become dumbbell shaped. If the fibers have been damaged, there is little resistance to the swelling, and the whole fiber segment swells uniformly without the formation of extrusions from the ends. By counting the number of dumbbell shaped, moderately swollen, and unswollen ends, a semi-quantitative evaluation can be made by which one sample may be compared with another in any experimental series.

Fragmentation. Another method of comparing samples for extent of damage is to compare their response to beating in water. Normal cotton

fibers, when beaten in water, as in a Waring blendor[1] or papermakers' beater, fibrillate to produce long, hairlike fuzz on the fiber as it comes apart into a mass of fibril aggregates resembling strings. In cases of severe damage, as in scorching by heat, or excessive degradation due to high energy radiation, the weakened fiber breaks into short fragments without any longitudinal splintering at all. This friable nature is characteristic also of acid-damaged cotton. One concludes that it is the result of breakage of many bonds in the long cellulose chains which make up the microfibrils. Usually, by the time this effect is noticeable microscopically, the drop in degree of polymerization is marked.

Electron Microscopy

Electron microscope observations permit comparison of much finer details of structure than those seen by light microscopy and provide additional criteria for evaluation of cellulosic materials. By replication, surface topography of fibers may be studied to investigate the progressive effects of such processes as scouring, bleaching, coating and impregnation, and derivative formation (14), of the physical phenomena associated with abrasion, heat damage, microbial degradation, or beating and grinding processes. It is possible to observe snags in the primary wall,

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1/ Use of a company and/or product named by the Department does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

disruption of the winding layer, splintering of the secondary wall, compression faults, cracks in the fiber, and cuts in the cell wall, and other phenomena associated with fiber damage of various types.

Electron microscope observations of the fine fragments developed in beating fibers in water will show much about the character of degradation the fiber may have suffered. For instance, hydrolysis and enzymolysis result in the development of characteristic micelles (8), and fragmentation of esterified cellulose produces spongy fibrillar masses interspersed with lumps of amorphous material (15).

With the above-described tests as tools for examination of fiber damage, it is pertinent to consider phenomena observed in typical damage situations.

Damage Patterns

Microbial Damage. Cotton is often subject to microbial attack. Even in the field before harvest, fungi and bacteria sometimes degrade the quality of the fiber. The mechanism of such microbial attack is the hydrolysis of the cellulose by the enzyme secreted by the organism in growth. These enzymes dissolve out the cellulose by breaking it down into simpler compounds, thus deriving food from the cotton for further growth of the organism (4). Microbial damage results in localized breaks in the fiber wall, and in hydrolytic damage to the cellulose, both of which may be demonstrated by staining. Presence of micro-organisms may be shown by application of lactophenol blue. Microbial bodies are stained deep blue against a pale blue or colorless background.

A 1% aqueous solution of gentian violet renders microbial hyphae and spores deep purple. If the fiber is subsequently swelled in 10% sodium hydroxide, the micro organisms stand out brilliantly against an almost colorless fiber. Proteinaceous residues within the lumen of unpurified fibers will also stain with gentian violet, but characteristic morphology will indicate fungal growths if organisms are present.

One can usually observe localized breaks and fractures in the fiber wall, and even gaping holes in the secondary wall, and in some cases a finely checkered, friable condition of the extremely thin fragment of wall which remains. This thinning of the wall is particularly noticeable in bacterial degradation in the later stages.

With the electron micrpscope, observations on both bacterial and fungal enzymolysis of cotton (8) indicated that the damage differed little from that of hydrochloric acid damage except that the attack of organisms is localized to areas on the fiber in which the organism is growing, whereas attack by the acid is uniformly dispersed in all parts of the fiber accessible to acid solutions.

Effects of Heat. Much has been said about the effects of heating on cotton. Unfortunately, mild damage by heat is not detectable microscopically. By the time pronounced effects are noticeable microscopically, the yellowing of scorching is also well-developed and the degree of polymerization is considerably reduced. Cotton yellows after five hours' exposure in air at 120° C. Samples heated for two hours at 200° C. were decidedly brown, but when mounted in water for examination under the microscope, they differed not at all from normal unheated cotton fibers except in color. Mounted in 10% sodium hydroxide on a slide for ten

minutes, the fibers began to show numerous cracks, transverse to the fiber axis, and, in places, actually to go into solution. However, in 20% sodium hydroxide swelling obliterated these breaks in the wall so that they were very difficult to detect.

Staining with ruthenium red, Nile Blue sulphate, or methylene blue shows slight differences between unheated and severely damaged samples, but the only really satisfactory test is the swelling behavior in cellulose solvents in which undamaged samples produce balloons, and the heat-damaged samples swell uniformly along the fiber length without ballooning (7). Staining with Nile Blue sulphate before swelling will make these observations more precise. In all such cases it is a prime requisite that control samples be run parallel to those being tested. Primary wall fragments obtained by beating in water fibers which had been severely heated, appeared to be set in the wrinkled conformation they had had on the fiber, and did not flatten out in water, as was the case with such fragments from normal fibers (13). A similar phenomenon was observed in fibers subjected to glow discharge treatments.

Acid Damage. Acid damage on the fiber can be readily shown by immersing the fiber in alkaline solution. It immediately breaks up to yield short horizontal segments of the fiber. In old texts on microscopy, this phenomenon was termed "chemical sectioning." With the electron microscope, the presence of the short, rice-shaped micelles of hydrocellulose is characteristic.

Damage by High Energy Radiation. Evaluation of changes in structure of cotton fibers after exposure to gamma, high-energy electron and thermal neutron radiations was made by optical and electron microscopy (9). Radiant exposures evaluated were: gamma rays, 10^5 to $4x10^8$ r.; 2-Mev electrons, $5x10^4$ to 10^8 rep; integrated thermal neutron fluxes, $5x10^{14}$ to 10^{17} nvt. All irradiated cottons could be differentiated from unexposed cottons by optical microscopical observations of samples stained in Nile Blue sulphate. Gamma ray and electron-exposed samples differed from unexposed fibers in swelling behavior in cupriethylenediamine hydroxide, but thermal neutron irradiated cotton differed from the control only after exposure to an integrated flux of 10^{17} nvt. Electron micrographs of the fibrillation patterns exhibited by fibers exposed to gamma and electron radiation doses of $5x10^6$ to 10^8 r. or rep on beating in water showed the formation of increasingly smaller fragments of samples. Some shortening of fibrils and an increase in number of broken ends of microfibrils were seen in neutron-irradiated cotton exposed to 10^{17} nvt; at lower integrated neutron fluxes, fibrillation was unchanged. No distinct differences were found between gamma- and electron-irradiated fibers or between gamma-exposed fibers irradiated in oxygen and in nitrogen.

Abrasive Damage: In textile usage, the property most important in the durability of a fabric is its abrasion resistance. Abrasion may be considered to bring the useful life of a garment to an end in one of two ways: either it renders the fabric so thin, so shiny, or so hairy that it is discarded as unsightly, or it produces a progressive deterioration in strength until a level is reached at which the fabric is no longer able to withstand the stress of usage without rupture.

Abrasive wear is defined as the physical destruction of fibers, yarns, and fabrics resulting from contact with and relative motion of a textile surface over that of another surface such as metal, wood, dirt, another fabric, or on itself as in a fold or crease.

Possible mechanisms of abrasion are: plucking or snagging of fibers out of the yarn, cutting of fibers, frictional wear, and deformation and compression of fibers in flexing. Under a given set of conditions, abrasion damage might be considered to depend on: mechanical properties of the fiber such as stiffness, elasticity, toughness, elongation, etc.; yarn and fabric construction, for example, twist and weave; and finishing, such as protective coatings, softeners, binding materials, and crease-proofing additives.

Damage to many textile articles in actual service undoubtedly results from a combination of direct rubbing--commonly referred to as "flat abrasion," and flexing and bending--generally termed "flex abrasion." Loss of strength due to mechanical wear may take place because of breakdown of cohesion between fibers in the yarn, or breakdown of internal cohesion within the fiber. To investigate this latter mechanism, recent studies in this laboratory have been directed toward the microscopical observation of fiber damage under various conditions of abrasion.

Samples of fabrics of a plain weave construction were abraded to rupture on the Stoll abrader[3/] (1). The samples included grey fabric, kiered and bleached fabric, and mercerized fabric which had been resin treated by conventional processes for wash-wear purposes. Flex abrasion was compared with flat abrasion for the series, and in both, abrasion in the wet state was compared with abrasion in the dry state.

Light Microscope Observations. To observe effects of abrasion at the level of the individual fiber, samples were examined in the light microscope. Abraded samples were stained with Simons stain, a combination of dyes which rendered the damaged areas orange and the undamaged areas blue. Types of microscopical damage observed were: longitudinal splitting of the fiber, fragmentation of the broken ends to produce "brush ends," mashing or bruising of the fiber, and clean, sharp breaks. Identical types of damage were observed in both warp and filling of the strips of square-weave cloth used in these experiments.

Surface photographs at magnifications of as low as 30X of unabraded and abraded fabrics showed that the characteristically hairy surface of cotton yarns is much smoother after abrasion, and that the interyarn areas are much more open (Figure 1). Knobby stubs of broken fibers may

Figure 1. Photomicrographs of surfaces of square-weave cotton fabrics before (a) and after (b) abrasion. Magnification 30X.

be seen protruding from yarn surfaces and in the interyarn spaces. Photomicrographs of broken fiber ends from the edges of holes in samples abraded to rupture show similar types of damage.

In dry flex abrasion the chief characteristic is the longitudinal splitting of the fiber (Figure 2a). Samples flexed wet showed no splitting

Figure 2. Photomicrograph of broken fiber ends from cotton fabric flex-abraded to rupture. Magnification 300X. (a) Flexed dry. Note splitting of fiber. (b) Flexed wet. Note accumulation of fine detritus in mashed areas of fiber.

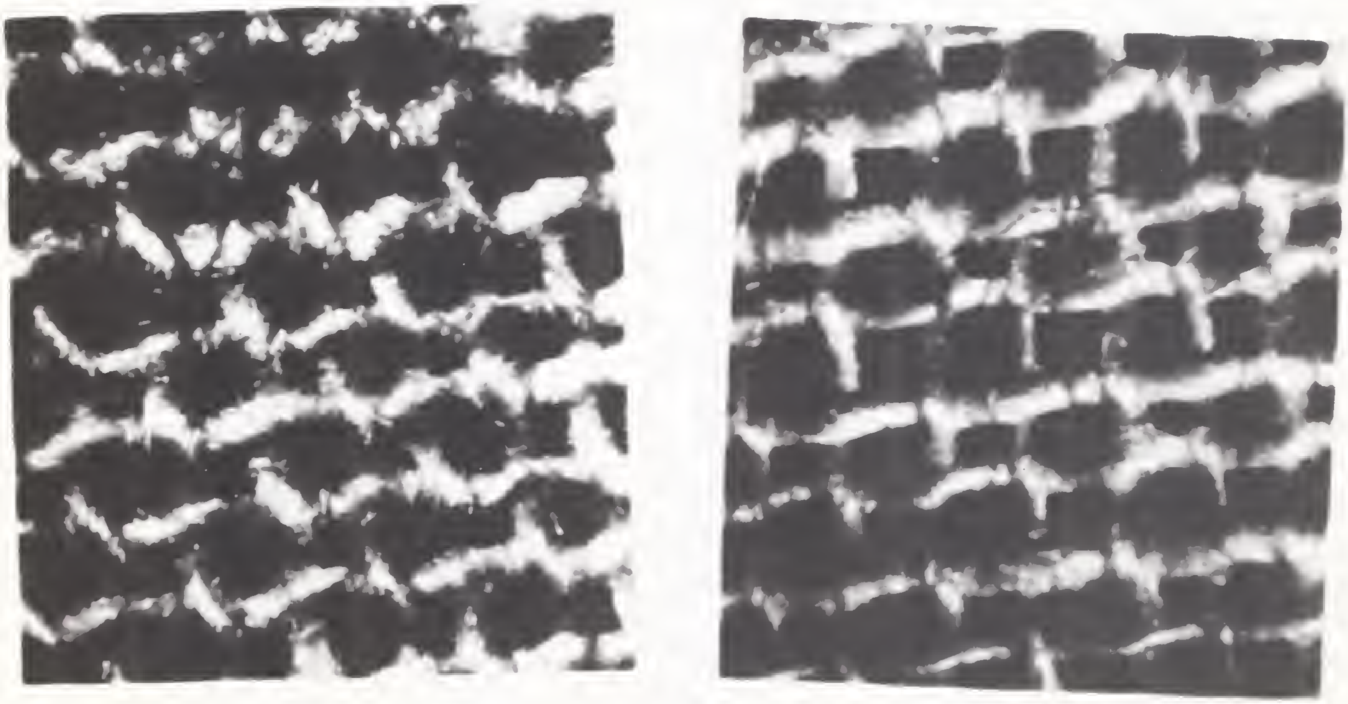

Figure 1. Photomicrographs of surfaces of 80-square cotton fabrics before (a) and after (b) abrasion. Magnification 30X.

In (a), note characteristic hairiness of yarns and excess of loose fibers on fabric surface.

In (b), note knobby stubbs of broken fibers between yarns and relative cleanness of fabric surface and inter-yarn spaces.

Figure 2. Photomicrograph of broken fiber ends from cotton fabric flex-abraded to rupture. Magnification 300X.

(a) Flexed dry. Note splitting of fiber.

(b) Flexed wet. Note accumulation of fine detritus in mashed areas on fiber.

of this type, but considerable fibrillation and much accumulation of masses and lumps of detritus on the splintered fiber fragments. (Figure 2b). It is obvious that there is considerably more damage in wet-flexing than in dry. This is in line with the observation that in flex abrading, wet samples rupture much sooner than dry samples of the same fabric. In untreated cotton the ratio of cycles to rupture is five to one.

As would be expected, resin-treated fabrics had a very low flex life. They showed no fragmentation in dry flexing (Figure 3a); the breaks

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Figure 3. Photomicrographs of broken fiber ends from resin-treated cotton fabric flex-abraded to rupture. Magnification 300X. (a) Flexed dry. Note short, clean-cut breaks. (b) Flexed wet. Note occasional fibrillation indicating nonuniform distribution of resin.

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were sharp and clean. Except for numerous breaks of this type, no other form of damage was noticeable on the fiber. Wet-flexed samples of this resin-treated fabric showed the same types of clean breaks for the most part, but with occasional fragmentation as in Figure 3b. The occasional fibrillation observed was interpreted to indicate isolated areas devoid of resin, due to inhomogeneity of treatment, the fiber being sufficiently affected by water to influence its pattern of breaking. In abrading to rupture, wetting appeared to improve resistance of resin-treated samples to abrasion by providing a certain amount of relaxation or lubrication. There was, however, little difference in the number of cycles to rupture in wet- and dry-flexed samples.

Electron microscope studied of fibers from flex abrasion experiments revealed changes in both surface topography and in internal structure.

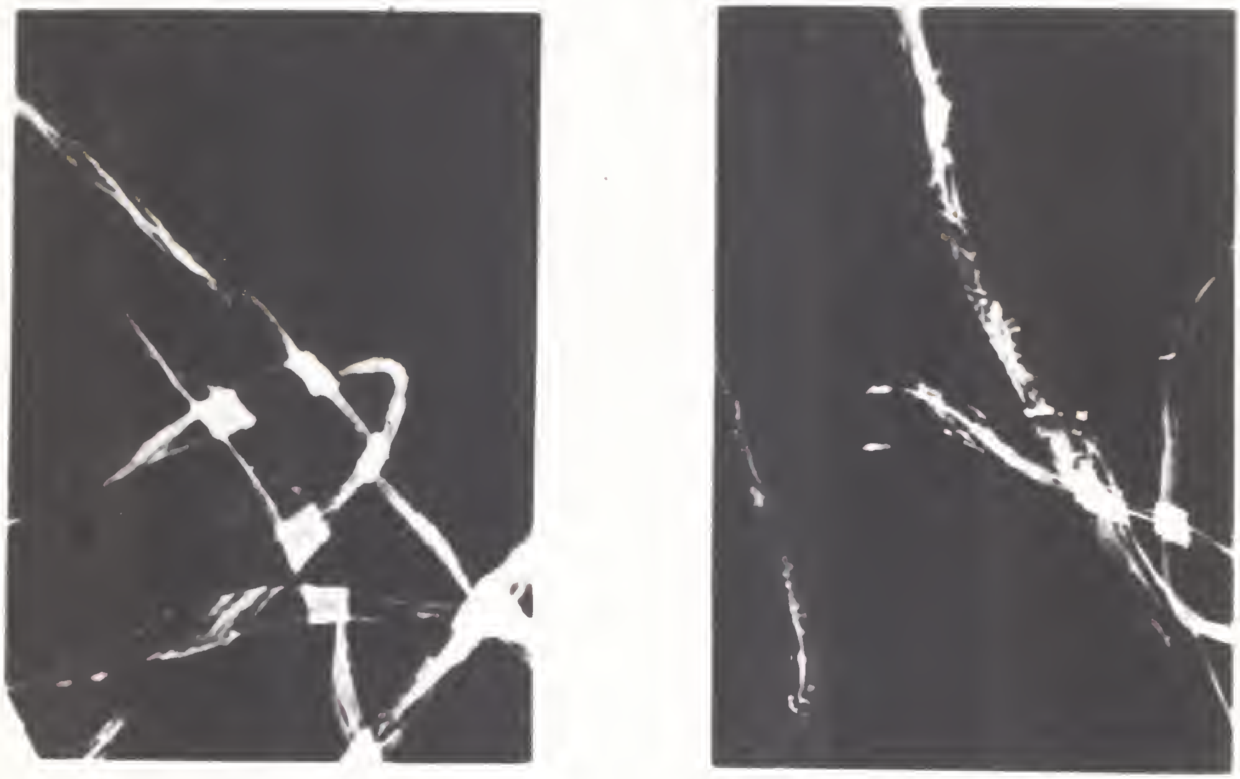

Figure 3. Photomicrographs of broken fiber ends from resin-treated cotton fabric flex-abraded to rupture. Magnification 300X.

(a) Flexed dry. Note short, clean-cut breaks.

(b) Flexed wet. Note occasional fibrillation indicating non-uniform distribution of resin.

In a good many instances small wedge-shaped fractures were observed at the edges of flexed fibers as if they had been pinched out by the flexing motion. In the case of fibers flexed dry, there is an apparent smoothing out of the natural corrugation or wrinkling of the surface of the fiber. In addition, cracks both transverse and parallel to the fiber axis are in evidence (Figure 4a). In the case of fibers flexed in the wet condition,

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Figure 4. Electron micrographs of surface replicas of fibers from fabrics flex-abraded to rupture. Magnification approximately 4500X. (a) Flexed dry. Note smooth surface and fractures in both horizontal and longitudinal directions. (b) and (c) Flexed wet. Note progressive fibrillation and peeling of fiber.

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the fiber surface is very much disturbed, the outer layers sloughing off in long tangles of fibrils to reveal the peeled secondary wall beneath (Figures 4b and 4c).

In flat abrasion tests on the Stoll abrader, the fabric under tension is rubbed against an abradant surface, such as emery cloth, and the effects are much more drastic than in flexing. Fiber surfaces are seen to be snagged and cut, not only at the fiber ends where break occurred but throughout the fiber length (Figure 5a).

Figure 5. Dry flat abrasion. (a) Photomicrograph of fibers from cotton fabric abraded to rupture. Magnification 300X. (b) Electron micrograph of surface replica of fiber from cotton fabric abraded to rupture. Magnification approximately 4500X. (c) Electron micrograph of particle of detritus collected on fibers from fabric abraded to rupture. Magnification approximately 7,000X.

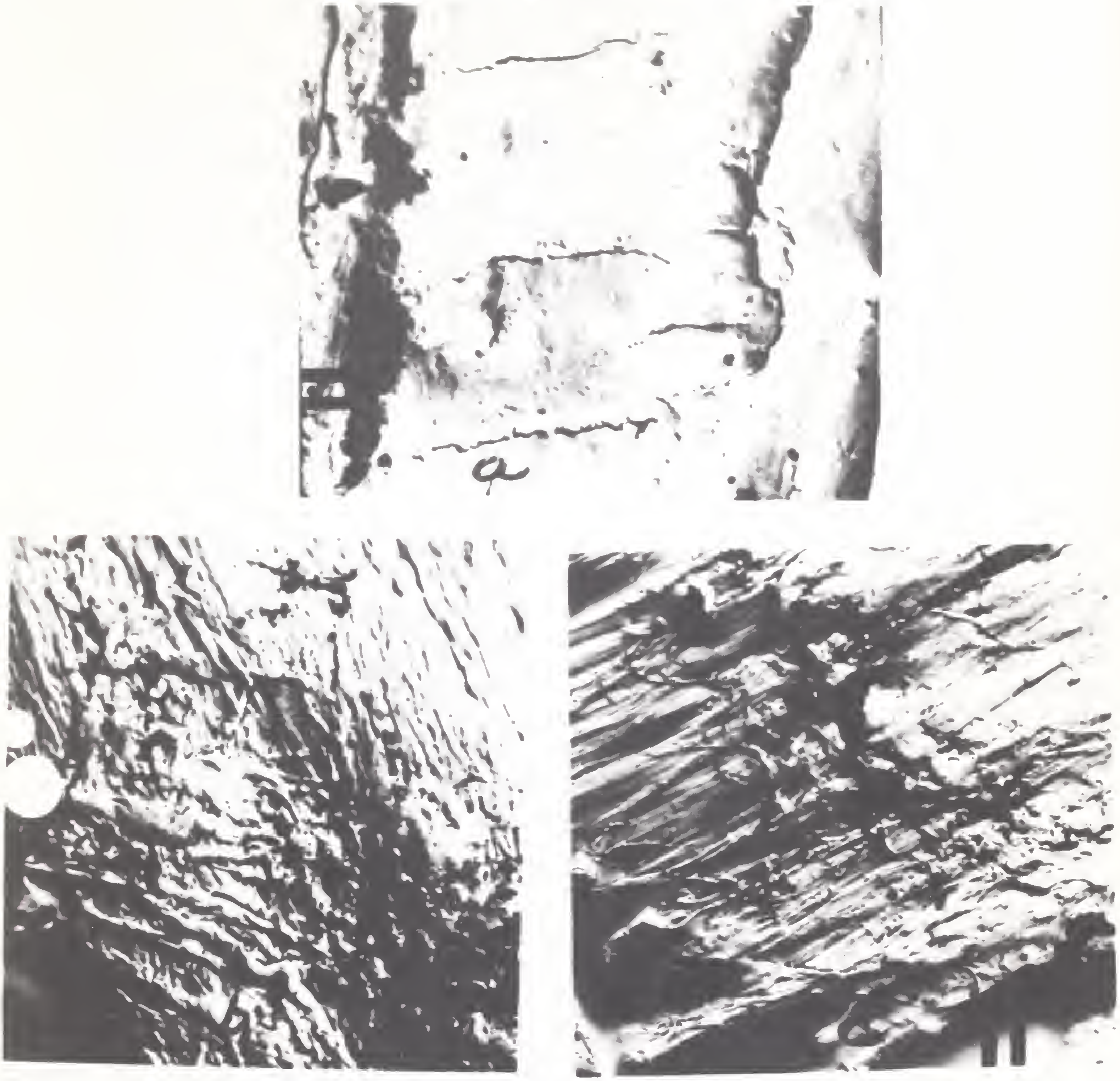

Figure 4. Electron micrographs of surface replicas of fibers from fabrics flex-abraded to rupture. Magnification approximately 4500X.

(a) Flexed dry. Note smooth surface and both longitudinal and horizontal fractures.

(b) and (c) Flexed wet. Note progressive fibrillation and peeling of fiber.

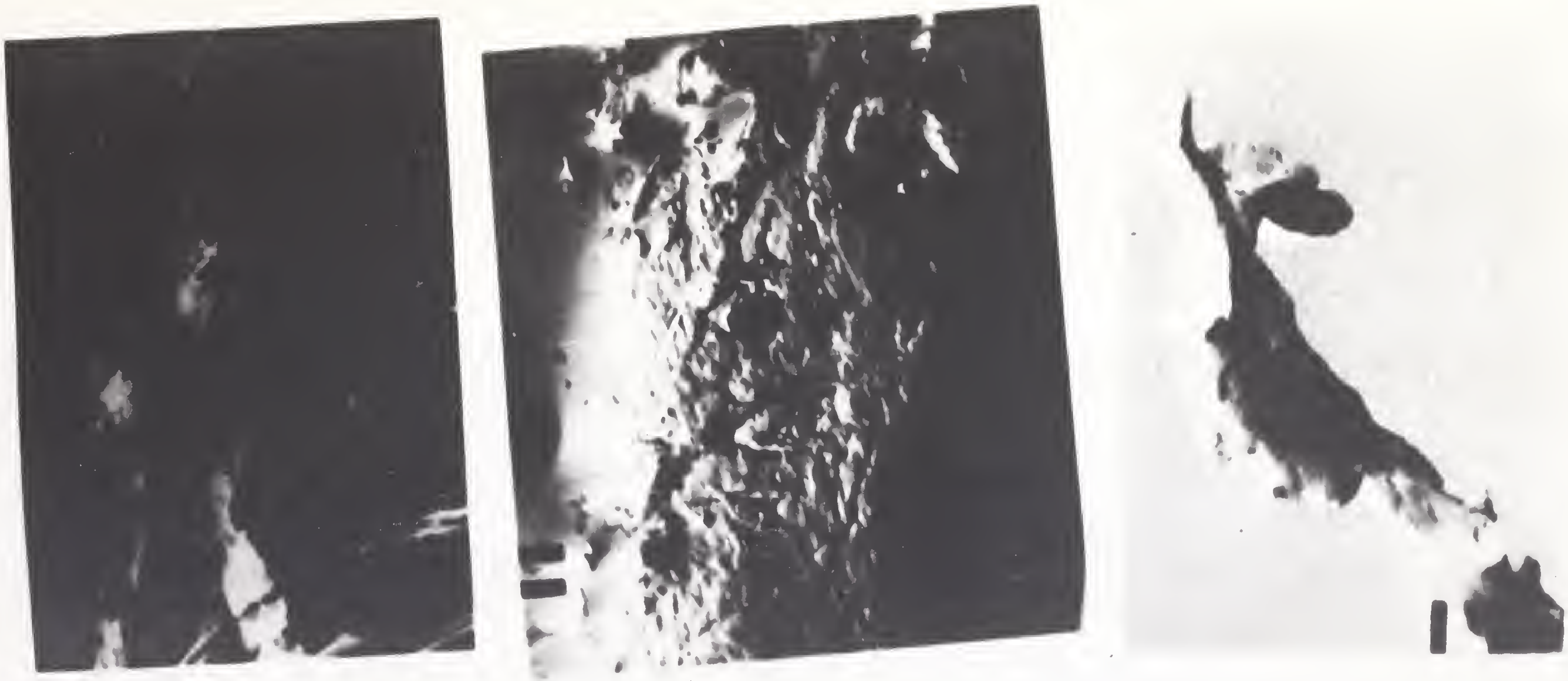

Figure 5. Dry flat abrasion.

(a) Photomicrograph of fibers from cotton fabric abraded to rupture. Magnification 300X.

(b) Electron micrograph of surface replica of fiber from cotton fabric abraded to rupture. Magnification approximately 4500X.

(c) Electron micrograph of particle from detritus collected on fibers from fabric abraded to rupture. Magnification approximately 23, 000 X.

Electron micrographs of replicas of the fiber surface show in detail the degree of gouging the fiber has suffered (Figure 5b). Careful consideration of the fine fragments which collect as detritus on the fibers is even more instructive (Figure 5c).

Figure 6 shows a similar series of pictures from samples which had

Figure 6. Wet flat abrasion. (a) Photomicrograph of fibers from cotton fabric abraded to rupture. Magnification 300X. (b) Electron micrograph of surface replica of fiber from cotton fabric abraded to rupture. Magnification approximately 4500X. (c) Electron micrograph of particle of detritus collected on fibers from fabric abraded to rupture. Magnification approximately 7,000X.

been flat abraded in the wet condition. It is obvious that wetting of the fiber permits separation of fibrils and a certain amount of splintering not seen in the fiber abraded in the dry condition. The electron micrograph of the fiber surface (Figure 6b) and of the fragment of detritus (Figure 6c) collected from the abraded fiber bear out this interpretation. In flat abrasion the effect of wetting on the resistance of the fabric to wear, as judged by the number of cycles to rupture is negligible.

A careful comparison of the illustration in Figures 5 and 6 will convey the characteristic differences in the microscopical aspects of flat abrasion in the dry and wet states. By the same token, a close comparison of Figure 2a with Figure 5a, and of Figure 2b with Figure 6a, will bring home the characteristic differences to be expected between flex-abrasion and flat-abrasion, as revealed in microscopical evaluation of fiber damage.

Figure 6. Wet flat abrasion.

(a) Photomicrograph of fibers from cotton fabric abraded to rupture. Magnification 300X.

(b) Electron micrograph of surface replica of fiber from cotton fabric abraded to rupture. Magnification approximately 4500 X.

(c) Electron micrograph of particle from detritus collected on fibers from fabric abraded to rupture. Magnification approximately 23,000X.

An interesting appraisal of the effect of resin treatment on abrasion resistance may be had by studying the sequence of micrographs in Figure 7.

Figure 7. Effect of resin treatment on flat abrasion. (a) Photomicrograph of fibers from resin-treated cotton fabrics after wet flat-abrasion to rupture. Magnification 300X. (b) Electron micrograph of surface replica of fiber from resin-treated cotton fabric flat-abraded to rupture in the wet state. Magnification approximately 4500X. (c) Electron micrograph of particle from detritus collected on fibers from resin-treated cotton fabric flat-abraded to rupture in the wet state. Magnification approximately 7,000X.

It is obvious that bonding of microfibrils has restricted the fibrillation of the fiber in abrasion, but that when abraded wet, whole sheets of fibrils can be torn out by the sharp edges of the abradant particles.

These microscopical observations are not conclusive, but they illustrate the fact that there is considerable comparative information to be had by the microscopical and electron microscopical study of types of damage the cotton fiber will exhibit under specific conditions of attack. Because of the tremendous sampling problem involved in microscopical studies of cotton materials, it is unlikely that these observations can be used as standard testing procedures for determining whether or not damage has occurred. Such determinations rest on changes in breaking strength and in rate of moisture absorption, or in degree of polymerization, in alkali solubility, and similar tests on gross samples of the yarn or fabric. It is obvious from the examples cited

Figure 7. Effect of resin treatment on flat abrasion.

(a) Photomicrograph of fibers from resin-treated cotton fabric after wet flat-abrasion to rupture. Magnification 300X.

(b) Electron micrograph of surface replica of fiber from resin-treated cotton fabric flat-abraded to rupture in the wet state. Magnification approximately 4500X.

(c) Electron micrograph of particle from detritus collected on fibers from resin-treated cotton fabric flat-abraded to rupture in the wet state. Magnification approximately 23,000X.

here, that much auxiliary and explanatory information can be developed by the use of microscopy as a preliminary tool for investigation of the causes and mechanism of damage in cotton; and that, to some extent, microscopical appearance can be related to the mechanical and chemical history of the specimen.

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SECOND SESSION

Chairman: George S. Buck, Jr.

DRYING AND CLEANING EFFECTS ON FIBER PROPERTIES

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Southern Utilization Research and Development Division
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The removal of excess moisture from seed cotton and the separation of trash from the fibers by mechanical working are essential processes before marketing mechanically harvested cottons. The mechanical working of fibers to remove the remaining trash and to align the fibers is continued in the textile mill. The ease of accomplishing the objectives and the resulting fiber damage are related to the moisture within the fiber. Moist fibers are more difficult to separate from trash than dry fibers. In contrast, fibers are stronger and more pliable when moist than when dry. Also, their ability to withstand impact from machine parts during cleaning at the gin and mechanical processing at the textile mills is greater for normal moisture fibers than for dry fibers. Since both normal and low moisture conditions have advantages frequently within the same process, a compromise in the amount of moisture is necessary to produce the best results with the minimum fiber damage.

Cotton fibers, passing through the processes between harvesting and weaving, are contacted by sharp edges of metal parts, such as gin saws,

teeth of lint cleaners, opener and beater blades, licker-in teeth, and card clothing wires. Many fibers break while others have their cell walls damaged by their contacts. In the present report, the damaging effects of several processes on the fibers will be discussed. In addition to permanent changes in fiber properties, temporary effects such as strength decrease with moisture loss and the permanent effects of drying on fiber structure will be related to the physical behavior and changes during mechanical working. Samples for the investigation of fiber changes were secured from those provided by the U. S. Ginning Research Laboratory, Stoneville, Mississippi, for cooperative investigations of spinning behaviors of gin dried and cleaned cottons.

Discussion of Results

Drying Gradients. During laboratory drying of single locks of cotton, a temperature gradient is found between the inside and outside of the locks, also between the base and tip of the fibers. After ten seconds in a stream of air at 220° C., a temperature gradient of 23° C. exists between the base and the tips in a dry lock of cotton, while in a moist lock the gradient is 36° C. The gradients decrease as the locks remain in the hot air, but in neither the dry nor moist locks do the temperatures within reach that of the drying air in less than one minute (Figure 1). Within the short pre-ginning period of drying, it is

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Figure 1. Temperature gradients between surface and inside positions for moist locks (A) and dry locks (B).

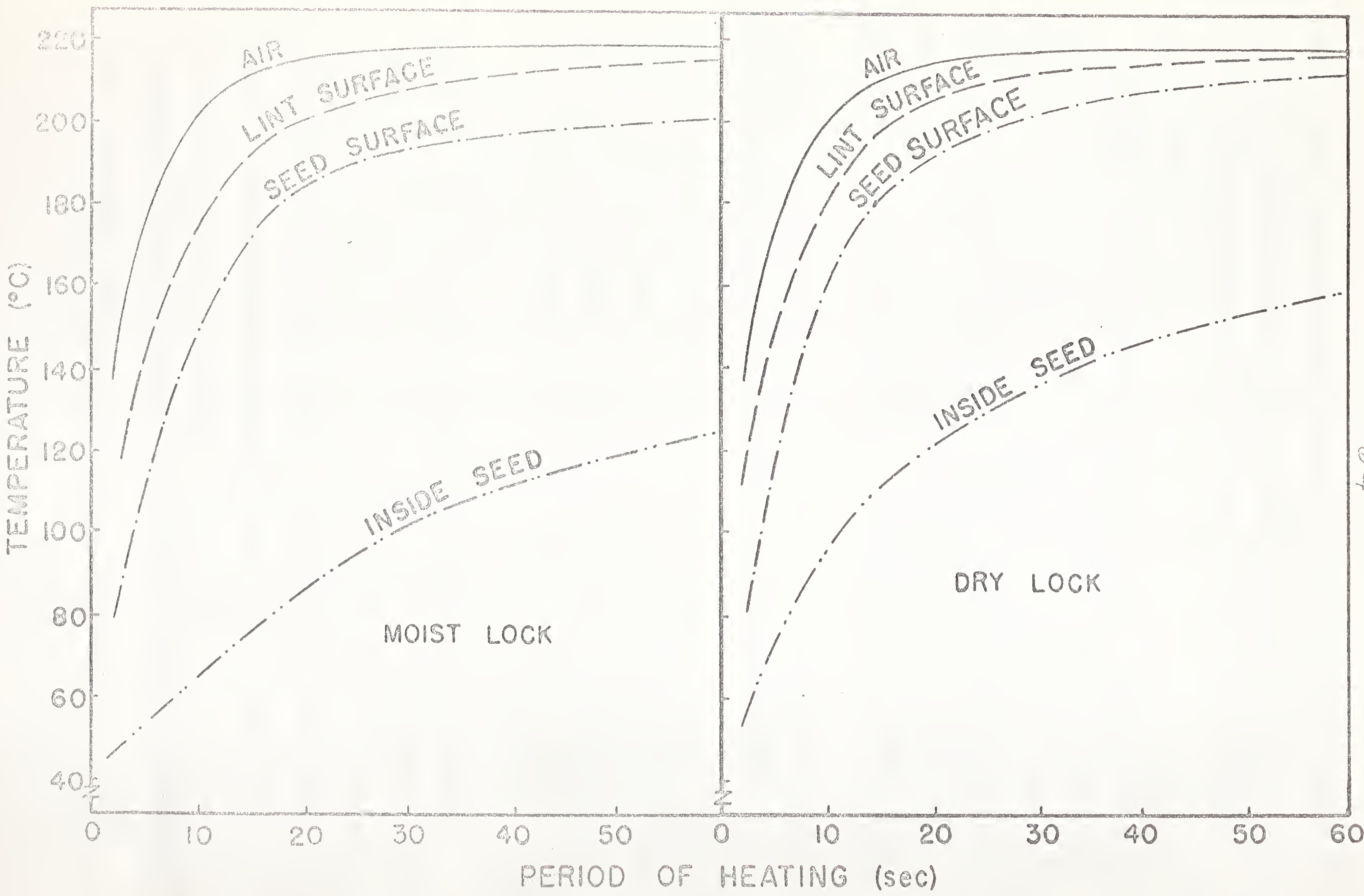

AIR
LINT SURFACE
SEED SURFACE
INSIDE SEED
MOIST LOCK
DRY LOCK
TEMPERATURE (°C)
220
200
180
160
140
120
100
80
60
40
0
10
20
30
40
50
60
PERIOD OF HEATING (sec)

Fig. 1

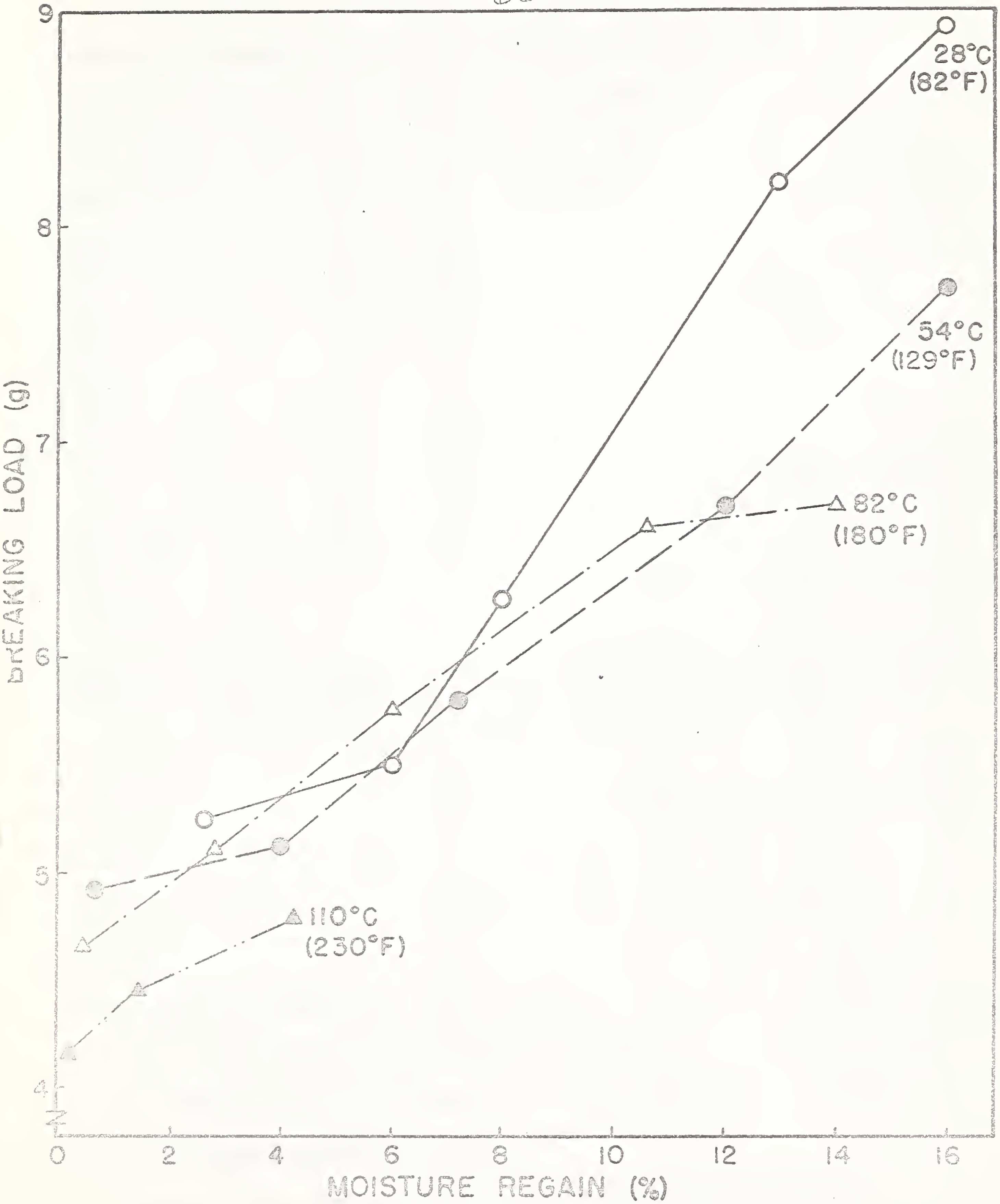
unlikely that fibers within the lock reach the initial temperature of the drying air since the hot air does not readily penetrate the mass of fibers, and the evaporation of moisture from fibers and seed cools the fibers near the seed.

Strength. Since a temperature gradient exists, a moisture gradient must also exist in locks in either the laboratory oven or gin machinery before reaching the saws. The temperatures of the fibers are approaching the temperatures of the surrounding air and the fibers are rapidly losing their moisture. Both loss of moisture and increase in temperature temporarily reduce the strength of the cotton fiber by 20 to 50% (Figure 2).

Figure 2. Effects of moisture and temperature on breaking loads of cotton fibers.

These fibers, thus weakened, are contacted by saws during ginning and by teeth in the lint cleaners. Gin-dried fibers after resorbing moisture have strengths essentially equal to those before heating.

Cell Wall Damage. The decrease in fiber length and the increase in quantity of short fibers after ginning and cleaning excessively dry fibers have been observed in many investigations. In addition to decrease in average length and a shift in the fiber length distribution, other properties of the fibers are affected. The cell wall of the fiber is damaged by both excessively high temperatures during the drying and mechanical abrasion in gin cleaning. Further damage to the cell wall by abrasion occurs at the textile mill during the mechanical processing of lint into a card sliver.


BREAKING LOAD (g)
MOISTURE REGAIN (%)
28°C
(82°F)
54°C
(129°F)
82°C
(180°F)
110°C
(230°F)
9
8
7
6
5
4
0
2
4
6
8
10
12
14
16

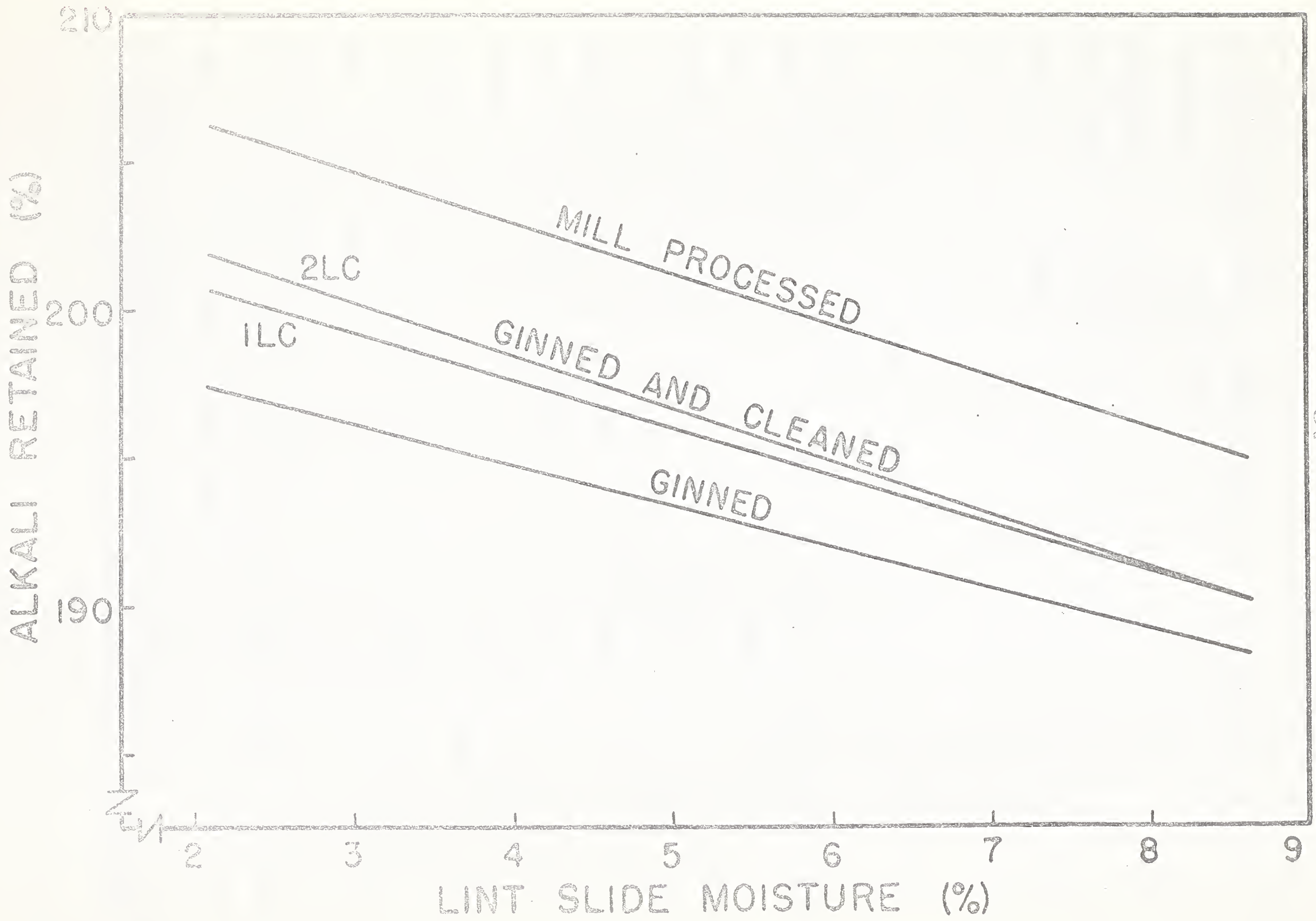
If the cell wall is damaged by heat-drying and/or abrasion, the damage may be easily detected by swelling the fibers in alkali. The retention of alkali by the fibers after centrifugation is a measure of their swelling capacity which increases with cell wall damage. The alkali swelling-centrifuge test (1), developed to measure microbial damage, can be used to measure both heat and abrasion damage, even though damages produced at the gin and in the textile mill do not produce as great a differential in swelling capacity as that caused by the microbial attack. While the test is sufficiently sensitive to show the effects of the two types of damage, it does not separate them.

In a series of cottons dried and cleaned as the gins under several conditions, the swelling capacity increased with amount of heat-drying (Figure 3). The lint cleaners increased the swelling capacity but only

Figure 3. Cell wall damage, as estimated by alkali swelling-centrifuge values, caused by heating and cleaning cotton fibers at the gin and processing into card sliver in the textile mill.

slightly more for excessively dried than for normal-moisture ("undried") cottons. In addition, mechanically processing the fibers into card sliver increased the swelling capacity by essentially equal amounts irrespective of the previous heating and cleaning processes. The combined cell wall damage caused by cleaning at the gin and processing the lint into card sliver is approximately equivalent, in this test, to the damage indicated by the difference in heating and ginning the fibers when lint slide moistures were 2% and 8%.

The cell wall damage, which can be estimated from the alkali swelling-centrifuge tests, can be observed microscopically in the fiber


MILL PROCESSED
2LC
GINNED AND CLEANED
ILC
GINNED
ALKALI RETAINED (%)
210
200
190
2
3
4
5
6
7
8
9
LINT SLIDE MOISTURE (%)

by swelling for excessive heat-damage and by dyeing for mechanical abrasion, but the effects of these damages on processing behaviors and product qualities are difficult to evaluate. However, quantitative evaluations for damages provide essential information needed to establish drying conditions and mechanical actions in working the fibers which accomplish the objectives with minimum damage. Closely associated with cell wall damage is fiber breakage which is known to affect the behavior and qualities of the lint.

Moisture. The excessive drying with heat of fibers in a laboratory oven lowers their equilibrium moisture regain; the magnitude of the decrease is dependent on the severity of the drying. Excessive heat-drying at the gin produces a similar effect; the maximum difference for extreme conditions, 8% to 2% at the lint slide, was about 0.5% in equilibrium moisture regain and decreased with time elapsed after ginning. The temporary effects of mill atmospheric conditions were somewhat greater since cottons, dried to different levels at the gin, were found to have actual moisture regain differences of 1% in bales after six months storage but only 0.2-0.3% as drawing slivers. The permanent effects, as shown by equilibrium moisture regains, become progressively less with time. Repeat cycling of dried and undried fibers between high and low levels of atmospheric moisture decreases the difference in standard equilibrium regain. Samples from the Industry-Wide Committee on Cotton Quality for the 1950 crop (2) show that after ten years of storage the differences in moisture regains at standard conditions between dried and undried are within the limits of error of the test method. Equilibrium

moisture regains of cottons heated until essentially no strength remains are only 1.0% below that of the unheated (3). Also, regains at standard conditions of cottons oven-heated at 107° C. for two hours are about 0.2% below the values before heating. Even though differences in equilibrium moisture regains of undried and dried fibers are small, evidence is found in other properties, such as density and brittleness, that heat-drying has altered the fiber structure.

Density. Density of the fiber cellulose increases with the amount of gin drying. As in moisture, the range in densities is very small with differences between undried and gin dried (8% to 2% gin slide moisture) of only 0.005 g/cc. Frequently, slight reversals or no changes from drying are observed indicating that unknown factors in the previous history has affected the response to heating. The difference between normally dried cotton (stored under average atmospheric conditions) before and after laboratory heating is not as great as the difference between undried lint and moist cotton excessively dried at the gin. The reason for the difference is not known, but previous history of cottons in the field could possibly offer explanations for some differences between cottons which do and those which do not change their density with heating.

Fiber Breakage. Fiber "brittleness" or the ease of breaking during the mechanical working is another property which indicates that the fiber structure is altered by excessive drying with heat. Excessively dried cotton mechanically worked with the Nepotometer had a greater increase in quantity of short fibers than did the undried. The greater breakage could be attributed to one or a combination of changes: the reduction of

moisture by heating, the degradation of the cellulose which decreased the strength, or the increase in rigidity by the formation of new stable molecular aggregates or crystalline regions. The increased rigidity which would be related to the changes in molecular aggregations or loss in moisture would be in agreement with the observations made by Berriman that the dried fibers are more kinky than the undried fibers (4). A less effective distribution of tensile stresses in such fibers appears likely.

Dyeing. The appearance of new crystalline regions, if sufficiently extensive, could be expected to have significant effects on the dyeing characteristics. Slight differences in shade between the dried and undried are detected when the most sensitive type of dye is used on the grey fabrics. The differences are extremely slight and decrease almost beyond recognition in scoured fabrics. Shade differences between fabrics made from undried and excessively dried cottons are much less than those for fabrics made from cottons of different varieties from the same growth area, or cottons of the same growth area and variety but produced in consecutive years.

Processing Behavior. Several other properties of the cotton fiber, such as changes in waxes and breakage of the cellulose chains, etc., are affected by heat-drying in the oven or at the cotton gin. The changes in most of the other physical properties as well as those discussed are very small and difficult to evaluate in relation to the spinning behavior. A possible explanation for poor spinning qualities of overdried cottons could be the composite effect from changes in many properties, such as kinkiness, surface, and length distribution, as well as the above. Among

these changes, fiber length is the most easily recognized, but length changes are affected by factors other than heat-drying before ginning. A change such as an increase in rigidity may be advantageous in the separation of trash from the fibers, but an increase in fiber breakage caused by greater rigidity could be detrimental in other mechanical processes.

The composite effects of excessive heat-drying and lint cleaning at the gin on processing behavior and qualities of the textile products are easily detected. When the lint has been dried to an extremely low level prior to ginning, the yarn breakage during spinning increases with seed cotton cleaning and with the extent of lint cleaning (Table I).

Table I. The effects of gin cleaning of dry cotton on the short fiber content and the end breakage during spinning.

When the moisture level in the fiber is high the effects of gin cleaning processes are reduced appreciably. Differences in fiber properties other than those changed by gin drying and cleaning also affect the spinning qualities. Growth conditions, varietal influences (5), and contamination of the lint with trash and products used in modern farming practices affect processing behaviors. During the same period that ginning practices were being changed, the mills were increasing their speeds to increase production. Both changes affect processing behavior and have challenged the producer, the ginner, and the textile manufacturer to find the causes for good and poor processing behaviors in cottons and to find for the problems solutions mutually agreeable to all groups.

TABLE I. THE EFFECTS OF GIN CLEANING OF DRY COTTONS ON SHORT FIBER CONTENT AND END BREAKAGE DURING SPINNING

Overhead cleaning	Lint cleaners	Fibers less than 1/2 inch 1/	Ends to break 2/
		(%)	
	0	11.6	76
Simple	1	12.0	85
	2	12.9	96
	0	10.8	84
Moderate	1	11.7	100
	2	12.6	117
	0	11.6	168
Elaborate	1	13.1	139
	2	11.4	245

1/ Lint from bales having lint slide moisture of 2-3%

2/ End breakage per thousand spindle hours for 5000 hour tests on 40/1 filling yarns with spindle speeds of 11,000 r.p.m.

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DISCUSSION

Mr. Fife: Would it be possible to distinguish visually between simple, moderate and elaborate overhead cleaning, that is, as the samples were received from the gin?

Mr. Grant: The trash content may theoretically be different but this could not possibly be distinguished because each cotton was sufficiently blended to mask the difference.

Mr. Ross: Is it recommended to use a humidifier at the gin to restore moisture?

Mr. Grant: This is a gin problem but moisture regain should be restored either at the gin or at the mill before processing.

Mr. Buck: You mean proper moisture improves processibility.

Mr. Grant: One of the slides showed that effect when moisture was and was not restored before mill processing.

Mr. Buck: Cotton variability is greater than changes caused by processing after heating at the gin. If improvement in

processing can be effected, it does not matter what was the cause. On the other hand, if the cause of poor processing can be identified, it can then be corrected.

Mr. Sharp: How was 14% moisture at 180° F accomplished?

Mr. Grant: This was a forced experimental condition.

Mr. Getchell: Were strength _vs_ moisture regain tests made on single fibers and, if so, what was the elongation relation and how did broken ends look microscopically?

Mr. Grant: Tests were run on single fibers but elongation was not measured because we didn't have the Instron then. No pictures were taken of the fibers.

Mr. Cheatham suggested that Mr. Grant state the spinning conditions for those interested. These conditions were: 1100 rpm; 40^s; 3.75 TM; 2-1/4 ring - conditioned at standard conditions 48 hours before spinning.

ORIGIN OF SHORT FIBERS IN AMERICAN COTTONS

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and

Henry D. Barker
Cotton and Cordage Crops Fiber Research Branch
Crops Research Division
Beltsville, Maryland

The quantities of short fibers in American lint cottons are frequently attributed to the amounts of drying and lint cleaning at the gin. The initiatory causes for some short fibers in lint cotton may precede ginning, since seed cottons may differ in their percentages of these fibers. Also, the cottons could differ in their potentiality for breaking during ginning and cleaning. Moore (1) found that, on the average, the fibers were longer on the chalazal or base end of the seed than on the micropylar end and that the average fiber length varied for seeds from different plants. In his article, the distribution of fibers by length and the quantity of short fibers for each position are not given. Nor are there any published data relating short-fiber content on the seed to varietal characteristics and environmental conditions. Wakeham (2) and Tallant (3) have shown that the short fiber content in lint removed by hand from the seeds was appreciably less than that in lint ginned from seeds. Since a study based on lint removed from seeds by hand is unrealistic for practical evaluation, these varietal and environmental studies are based on ginned lint.

In the present report, the percentages of fibers shorter than 1/2 inch in lint removed from seeds with a small experimental gin are given for cottons of sixteen varieties grown under widely different environments. Short fiber contents are compared among samples of ginned lint from commercial equipment when extremes were used in both drying and cleaning practices.

Contributing Influences

Variety. The effects of variety and environment, which included weather and soil, on the quantity of short fibers were determined for cottons produced in the varietal and environmental investigations for the crop years 1935, 1936, and 1937 (4, 5). Although the varieties tested are not representative of those now in commercial production, they illustrate the differences in quantities of short fibers which can be associated with both varietal characteristics and growth conditions. From some of the varieties studied, strains now widely used in commercial production have been derived.

Data are given (Figure 1) to compare the quantities of fibers

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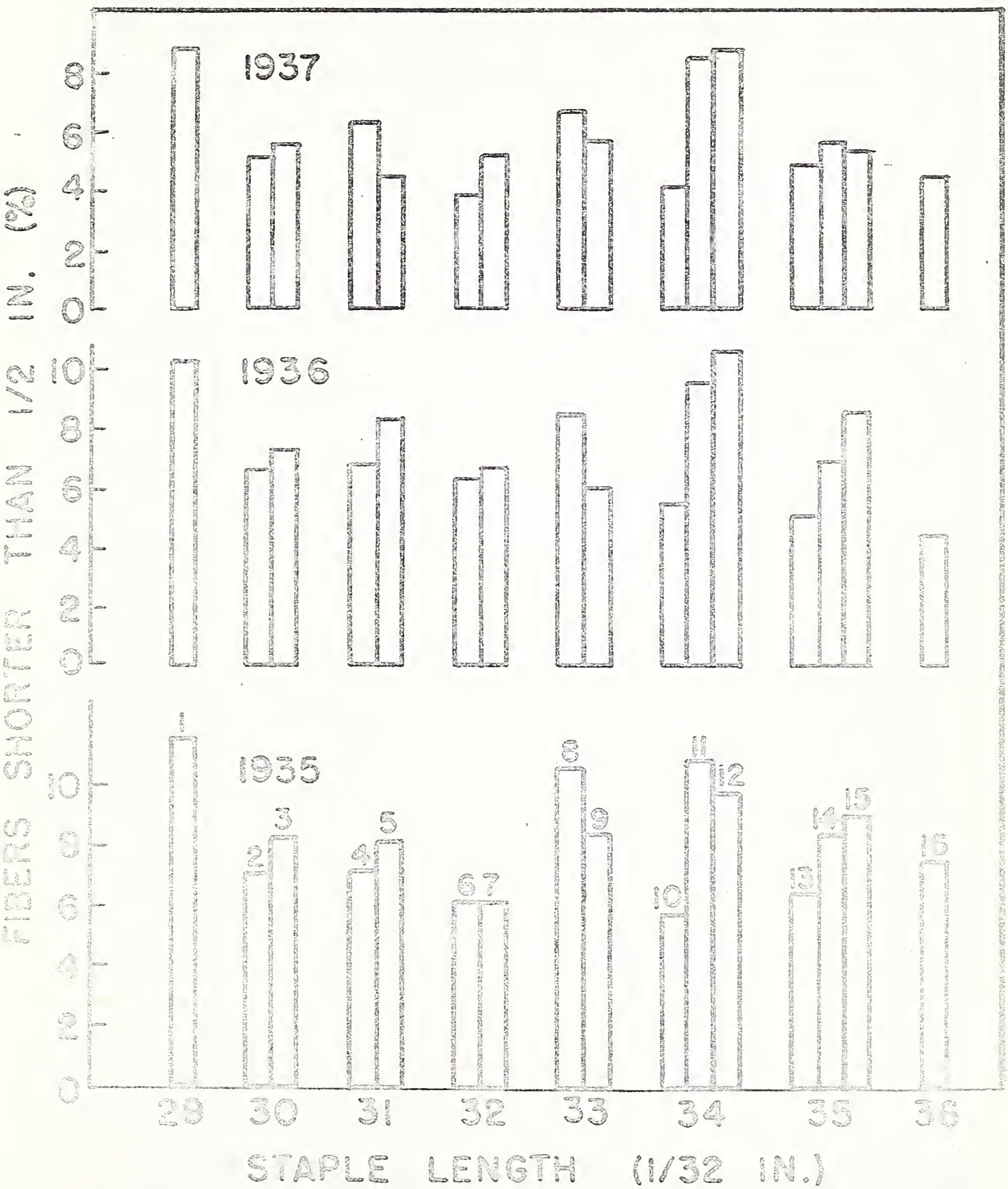
Figure 1. Percentages of Short Fibers in Cottons of 16 Varieties Grown at Knoxville, Tennessee, in 1935, 1936, and 1937. 1-Half and Half; 2-Cook; 3-Cleveland (W); 4-Dixie Triumph 759; 5-Triumph 44; 6-Rowden 2088; 7-Startex 619; 8-Qualla; 9-Stoneville 5; 10-Mexican Big Bill; 11-Farm Relief 759; 12-Deltapine 11; 13-Arkansas 17; 14-Delfos 4; 15-Acala (Rogers); 16-Wilds 5.


1937
1936
1935
FIBERS SHORTER THAN 1/2 IN. (%)
STAPLE LENGTH (1/32 IN.)
29
30
31
32
33
34
35
36
2
3
4
5
6 7
8
9
10
11
12
13
14
15
16

shorter than 1/2 inch for the 16 varieties grown at Knoxville, Tennessee, for 1935, 1936, and 1937. The rankings of these varieties by short-fiber content are remarkably consistent even though differences are noted in the levels produced in the different crop years. The rankings by short-fiber content are different from those by average staple lengths as given at the bottom of the graph. The staple length for a variety is an average of 42 samples produced under wide ranges in environmental conditions. The short-fiber content is an average from six arrays for samples from each environment. In several groups with two or three varieties having the same staple length, differences are found among varieties in short-fiber contents. Also, in both the short and medium staple cottons, varieties which produce either low or high quantities of short fibers are found.

These sixteen varieties grown in different areas during one crop year were similarly compared. The rankings of varieties by quantity of short fibers are very similar to those evident in Figure 1 for a single area for the three years. In many comparisons, the differences in level for crop years or for growth areas were small as compared with the range throughout the rain-grown cotton belt.

From these data, the varietal influences on short-fiber contents appear to be well established. The plants of certain varietal characteristics produce either higher quantities of short fibers than others or fibers which break more easily even when ginned under nearly ideal conditions. Equal staple-length varieties which produce high and low quantities of short fibers are found among cottons of short and medium staple lengths.

The causes could be breakage which reduces the original staple length and increases the quantity of short fibers or real differences in the lengths of fibers on the seed. Differences in short-fiber contents associated with variety even in comparable staple lengths ranged from 3 to 6% depending upon variety and are greater when staple-length differences are ignored.

Environment. Environmental effects on quantities of short fibers appear to be greater than varietal effects. In Figure 2, the short-fiber

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Figure 2. Short Fiber-Content of Stoneville 5 and Delfos 4 Varieties in 1935, 1936, and 1937, at Growth Areas: A-Statesville, North Carolina; B-Florence, South Carolina; C-Fort Valley, Georgia; D-Prattsville, Alabama; E-Knoxville, Tennessee; F-Jackson, Tennessee; G-Stoneville, Mississippi; H-Marianna (Upland), Arkansas; I-Marianna (Delta), Arkansas; J-Baton Rouge, Louisiana; N-Lubbock, Texas.

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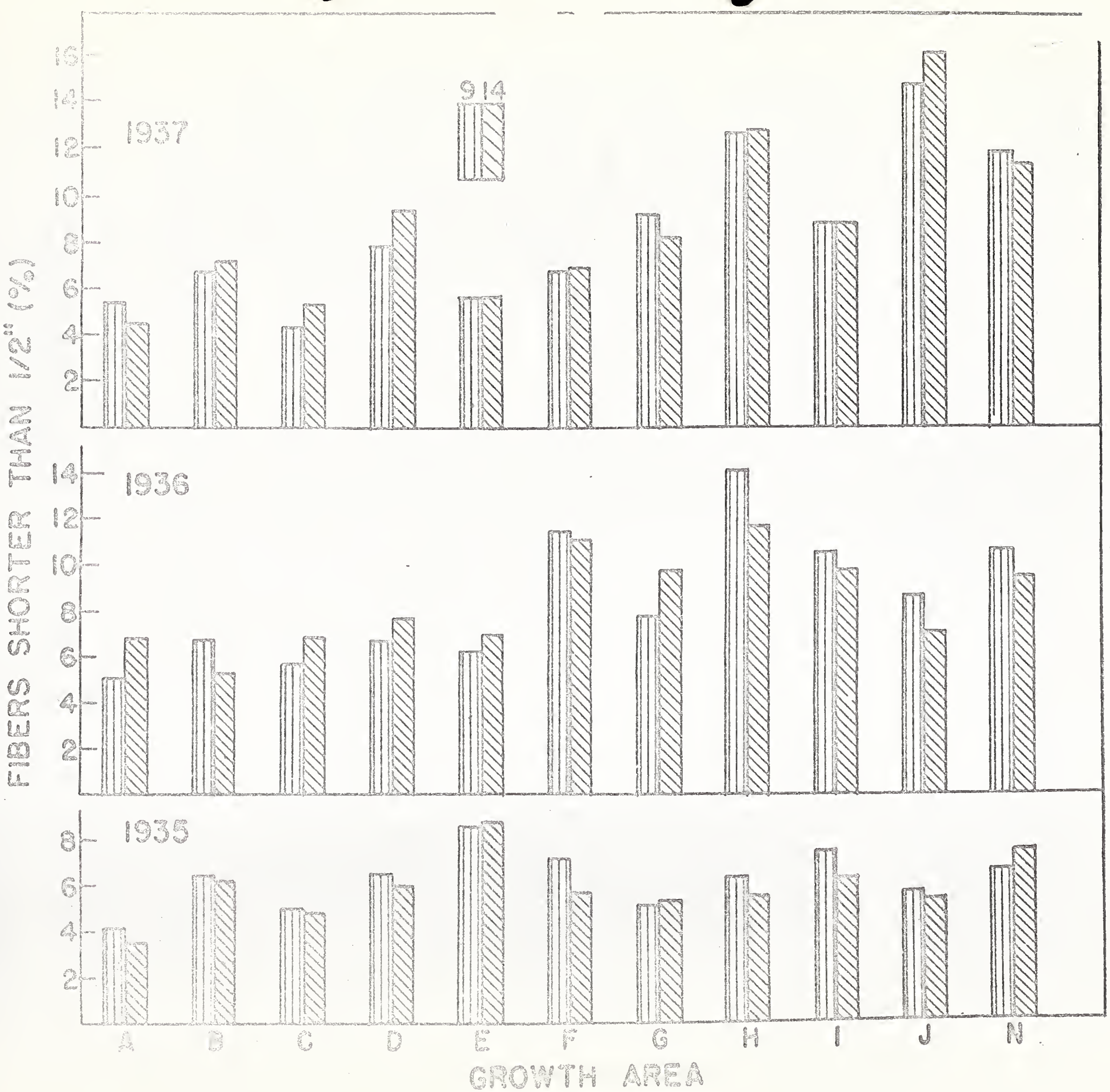
contents of the Delfos 4 and Stoneville 5 varieties are compared for wide ranges in environmental conditions. On the average, the short-fiber contents of the two varieties are essentially equal. Two of the crop-year averages were essentially equal (8.5 and 8.7%) but the other was appreciably different (6.6%). Also, the quantities were about equal for different growth conditions for each year even though the spread ranged from a low of 3.6% to a high of 16.4% during the three years. The high percentages in several growth areas can be attributed to weather conditions, and, if the data for these areas are eliminated, the spread would be decreased. Cottons on the High Plains during some of these years were produced under severe drought conditions, and at Baton Rouge, Louisiana, in 1937, excessive boll rot was evident.



1937
1936
1935
9
14
FIBERS SHORTER THAN 1/2" (%)
2
4
6
8
10
12
14
16
A
B
C
D
E
F
G
H
I
J
N
GROWTH AREA

Comparisons are given in Figure 3 for two other varieties, Rowden-2088

Figure 3. Percentages of Short Fibers of Rowden-2088 and Deltapine-11 Varieties in 1935, 1936, and 1937, from Growth Areas: A-Statesville, North Carolina; B-Florence, South Carolina; C-Fort Valley, Georgia; D-Prattsville, Alabama; E-Knoxville, Tennessee; F-Jackson, Tennessee; G-Stoneville, Mississippi; H-Marianna (Upland), Arkansas; J-Baton Rouge, Louisiana; L-Greenville, Texas; and N-Lubbock, Texas.

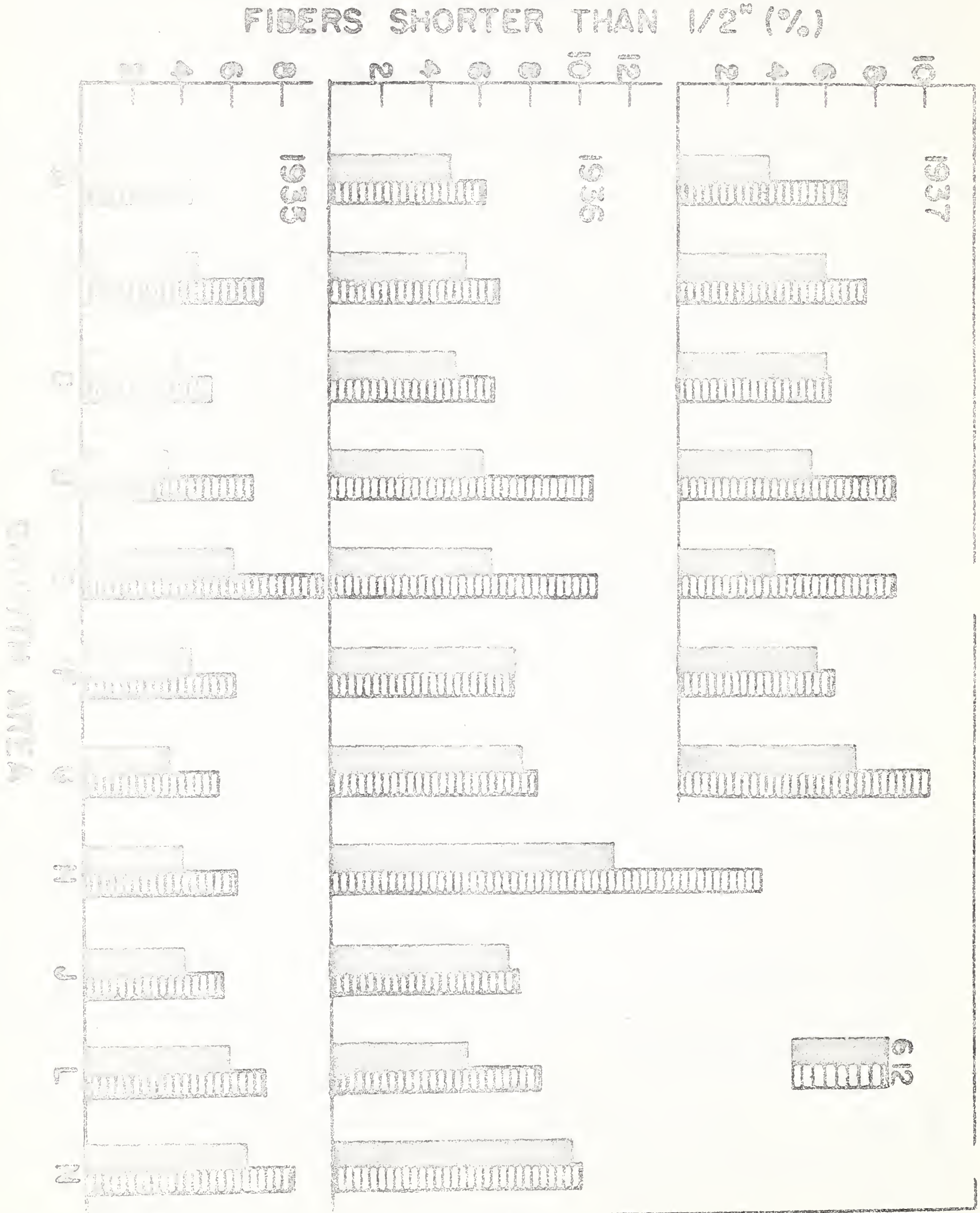
and Deltapine-11, which on the average produced low and high quantities of short fibers, respectively and consistently, in each of the growth areas.

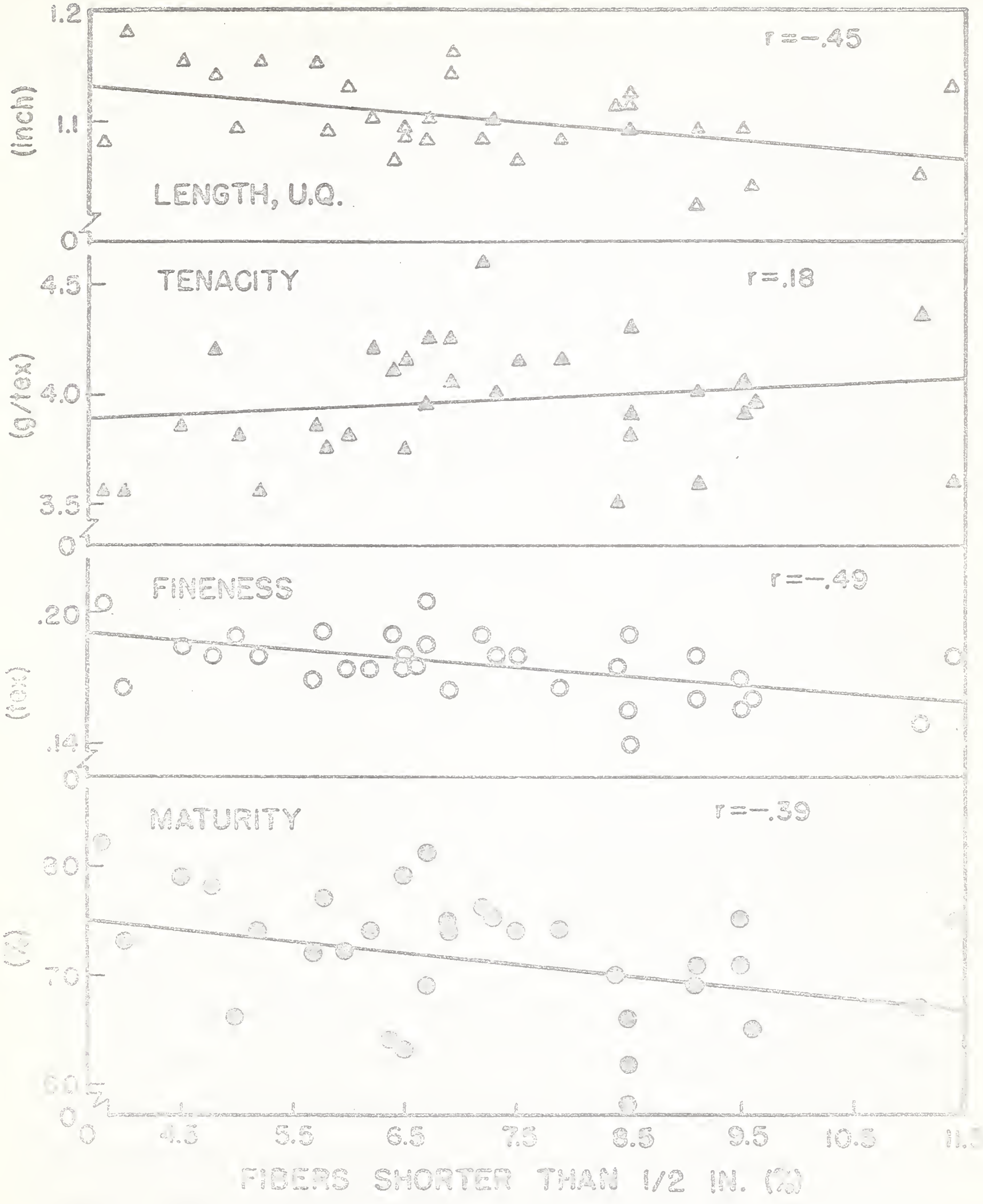
The relationships of short fibers to certain physical properties are not well defined because of the wide ranges in properties if all varieties are included in an analysis even though relationships might be expected. When ginning long fiber cottons, more fibers are expected to break than when ginning the short fiber cottons. Also, cottons with fibers having low breaking loads because of their low tenacity or size due to either maturity or fineness, could have higher percentages of short fibers than those with high breaking loads. The relationships become evident only when the short-fiber contents are compared for a single variety.

Fiber Properties. In Figure 4 are given the relationships of the

Figure 4. Relationships of Short-Fiber Content to Length, Tenacity, Fineness, and Maturity.

short-fiber contents of Stoneville variety to the fiber properties length


FIBERS SHORTER THAN 1/2" (%)
1935
1936
1937
612



LENGTH, U.Q.
(inch)
r = -.45
TENACITY
(g/tex)
r = .18
FINENESS
(tex)
r = -.49
MATURITY
(%)
r = -.39
FIBERS SHORTER THAN 1/2 IN. (%)

tenacity, fineness, and maturity. For tenacity the relationship is obscure even if it exists. However, for the others, the fiber length at the upper quartile decreases as the quantity of short fibers increases. Also, the quantity of short fibers increases as the fineness and maturity of the fibers decrease. The decrease in length with quantity of short fibers is indicative of fiber breakage which could be expected since fibers of the samples with lower upper-quartile lengths are finer and less mature. Relationships similar to those found for Stoneville were found also for the Delfos 4, Deltapine 11, and the Rowden 2088 varieties.

Crystal alignment, as indicated by X-ray angle, and the bundle strength at zero clamp spacing were greater for the Stoneville than the Delfos (6). Other measurements on these two cottons have shown that elongation-at-break and ratio of tenacity at 1/8 inch to that at zero clamp spacings were greater for the Delfos than for the Stoneville. While elongations and strength measurements are consistent with X-ray angle measurements of cellulose alignment, they do not explain the equal quantities of short fibers in these two cottons, unless the differences in fiber properties produce counteracting effects on breakage.

Ginning. Short fibers originate in almost every mechanical process which requires the mechanical working of the fibers. Fibers are broken in the gin and are carried with the unbroken fibers into the bale. Fiber breakage, as evident from the increase in quantities of short fibers with cleaning, is easily detected if the cotton is extremely dry when cleaned. Mill processes break many fibers, but the fragments as well as other short fibers are removed in part with waste. In the final

products, the quantity of short fibers is usually only slightly different from that in the ginned lint except in combed cotton from which most of the short fibers are removed.

Wide differences in quantities of short fibers are found in cottons ginned with modern equipment even though the ginning practices are identical. Extensive investigations have been undertaken to determine the causes of breakage in the different types of equipment. In general, breakage increases as the moisture is reduced below that of normal lint and if cleaning procedures are applied to the dry lint. Such factors as variety, growth conditions, harvesting practice, and weather damage influence the potentiality for breakage and the level from which increases in short-fiber content begins. The fiber properties responsible for differences in breakage during ginning without cleaning are expected to accentuate differences in breakage during lint cleaning. Furthermore, they are expected to affect breakage during subsequent cleaning processes and mechanical processing in the textile mill.

In Table I are given the quantities of short fibers in cottons from

Insert Table I.

similar and different ginning practices. The average for three of these samples ginned under mild conditions approximates that found in lint which had been ginned with the small experimental gin. Mild conditions are described as normal seed cotton moisture with only simple seed cotton cleaning and not more than one lint cleaner. Appreciably higher quantities were found in these cottons ginned with excessive drying and maximum amounts of seed and lint cleaning. Sometimes the environment alters

TABLE I. SHORT FIBERS IN EXPERIMENTALLY GINNED COTTONS[1/]

	Sample Identification	Picking Practice	Ginning Practice	Short Fiber Contents %
Series				
A	Acala 4-42 (1957)	Machine	Mild	7.5
	Acala 4-42 (1957)	Machine	Harsh	10.4
B	Delfos 7343 (1956)	Hand	Moderate	14.1
	Delfos 7343 (1956)	Hand	Harsh	15.7
C	Deltapine 15 (1958)	Hand	Mild	7.6
	Deltapine 15 (1958)	Hand	Harsh	12.8
D	Deltapine 15 (1958)	Machine	Mild	8.4
	Deltapine 15 (1958)	Machine	Harsh	12.2
E	Deltapine 15 (1960)	Hand	Mild	12.6
	Deltapine 15 (1960)	Hand	Harsh	17.1

1/ Cotton ginned with commercial equipment under controlled conditions of temperature and moisture.

this relation, e.g. the handpicked 1958 Deltapine-15 sample ginned with low moisture and two lint cleaners had 12.8% short fibers, while the 1960 sample ginned with low moisture and one lint cleaner had 17.1% short fibers. Similar comparisons made for other cottons have indicated that the short-fiber content is not always indicative of no drying or excessive drying and cleaning at the gins but results from many factors, such as the variety of cotton, the environmental conditions during growth, the method of harvesting, the moisture content when ginned, and the amounts of gin cleaning. In all paired samples the quantity of short fibers was greater in the sample excessively dried before maximum cleaning than in the sample ginned and cleaned under mild conditions, but samples with high short-fiber contents are sometimes found among cottons which were not excessively dried. Also, the short-fiber content of ginned lint is higher than that of lint removed by hand from the seed. Another factor affecting the short-fiber content is amounts of fuzz fibers removed by ginning.

Commercial Cottons

A comparatively small number of varieties produce commercial cottons of medium staple lengths. These varieties or their strains were selected for yield, staple length, strength, and other fiber properties as well as for plant characteristics. In above discussions, the effects of variety and environment on the quantity of short fibers produced have been demonstrated even though these data are not applicable to existing varieties. Interest of the textile industry in this measurement for cottons is too recent for complete analyses of present strains as to their potentialities

as producers of short fibers. In recent years research on ginning has been directed almost exclusively towards conditions which produce maximum lint quality with minimum damage to the fibers.

Production, harvesting, and ginning practices are changing rapidly to meet the demands of the textile industry. Meanwhile, the textile mills are increasing their machine speeds to increase production. The necessity for mechanical harvesting of seed cotton has increased the problem of supplying the textile mills with lint containing minimum amounts of trash. Trash affects the spinning properties of cotton, but even when processing cottons harvested without trash limiting machine-speeds exist.

Variety and environment affect the quantity of short fibers which, in turn, affects the processing behavior of cottons. Cottons of high short-fiber percentages, whether because of growth conditions or potentialities for breakage, could encounter serious difficulties in meeting the keen market competition among cottons or between cottons and synthetics. Since information is meager on the short-fiber potentialities of varieties now in commercial production, many questions now being asked about spinning qualities of American cottons cannot be answered. If more were known about the behaviors of different types of cottons during ginning and processing in the textile mills, comparisons could then be made between performance at the present and that of the past. Efforts could then be directed towards breeding strains which can be harvested with less trash, break less during ginning and cleaning, and have higher processing qualities in the textile mills.

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Discussion

Mr. Buck: The problem is to know whether the percentage of short fibers starts out so or does it result from processing stages. In other words, is the condition imposed or inherent?

Mr. Buck called on Dr. Hertel for comment. The latter stated that the picture was not clear from the evidence as to whether we should point a finger at the short fiber as the culprit. We need more fundamental information as the evidence is confusing. Previously we concentrated on fineness, then on strength, now on short fibers.

Mr. Grant: By the time the mill processes the fiber, the effect is a composite of all characteristics and not any one thing.

Mr. Buck reminded "Don't forget quality X?"

Mr. Hertel added "Any Y and Z?"

Mr. Buck: We advanced by concentrating on fineness and now we can measure fineness in every bale. (He implied that by concentrating on short fibers for awhile we may come up with some other measurement or another step forward.)

EFFECT OF SHORT FIBERS IN COTTON ON YARN AND FABRIC PROPERTIES AND SPINNING PERFORMANCE

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Cotton is subject to large environmental and varietal variation in its important fiber properties. A single measure of length, classer's length, has long been used as an important criterion of a cotton's spinning value. However, it is well known that two cottons having the same classer's length may have different spectra of length distribution, with one having significantly more short fibers than the other.

The influence of the shorter fibers in the cotton sample on the product quality and processing efficiency has been the source of much speculation but little quantitative examination. This has undoubtedly been because of the great difficulty involved in sorting out and measuring the various fiber length classes by techniques such as the Suter-Webb sorter.

The subject has been controversial and subject to conflicting reports apparently depending upon the manner in which the investigator measured "short fibers." For example, Webb and Richardson (12) reported from an analysis of 766 cottons that yarn properties were definitely affected by the Suter-Webb length coefficient of variation, with the

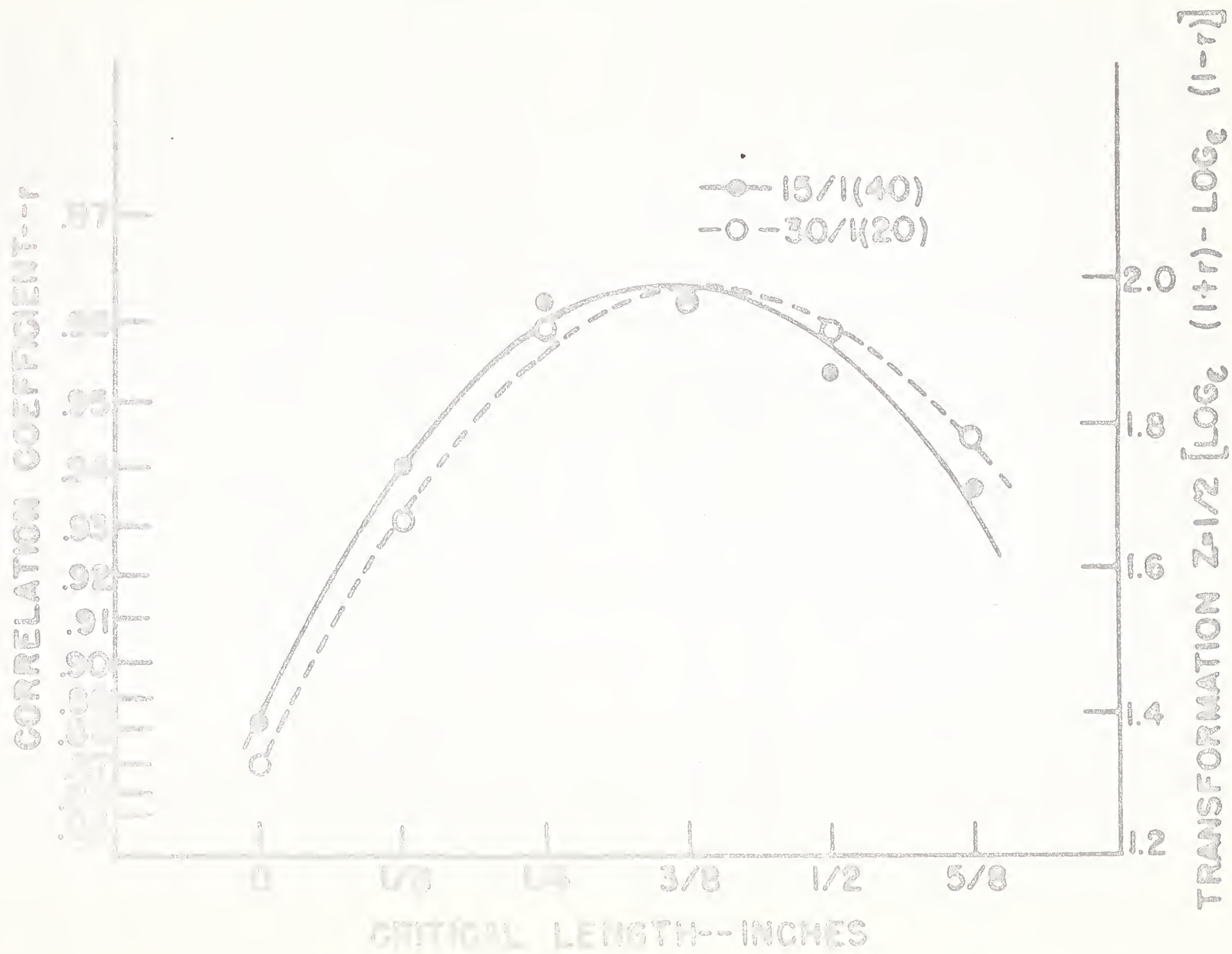
larger coefficients associated with a general deterioration in yarn properties. It may be reasonably inferred that the larger coefficients of length variation indicated to some extent larger amounts of short fibers. Subsequently, using a different measure, the Fibrograph length uniformity ratio, Webb (11) in an extensive statistical analysis with other fiber properties concluded that "length uniformity index made only a negligible effect on single strand count x strength product."

Both of these criteria of length distribution suffer from being inherently indirect measures of short fiber content. Consequently, it was decided to use as objective and direct a measure as possible. In 1934, Kohler (3) indicated that the "length of slippage" is approximately 8 mm. or slightly more. By this he meant that fibers 8 mm. or less are likely to slip rather than break when a yarn ruptures. Hence, these short fibers could contribute little to strength. With the Suter-Webb array a convenient division point between two cells is 3/8 in., or 9.5 mm.

Subsequent investigation utilizing a concept termed "effective weight" whereby not only the short fibers but also the tips of all longer fibers are considered unable to contribute to yarn strength has indicated that 3/8 inch is approximately the optimum measure (4). Figure 1 shows

Figure 1. Correlation of Effective Weight x Fiber Tenacity vs. Single Strand Tenacity for Various Critical Length Bases

… FIBER TENACITY VS. SINGLE STRAND TENACITY FOR … CRITICAL LENGTH BASES



the significantly better correlation of yarn with fiber tenacity (zero gage) obtained for 41 cottons when the effective weight calculated on a 3/8-inch basis is used. Effective weight is cumbersome to calculate and must be considered as only a research tool at present. The remainder of this paper will deal with the short fibers less than 3/8 inches only. However, it is recognized that many investigators are using as a criterion the percentage less than 1/2 inch. As an aid in conversion, Figure 2 is shown. The relationship between the

Figure 2. The Relationship Between Short Fiber Contents at 1/2 Inch and 3/8 Inch Upper Limits

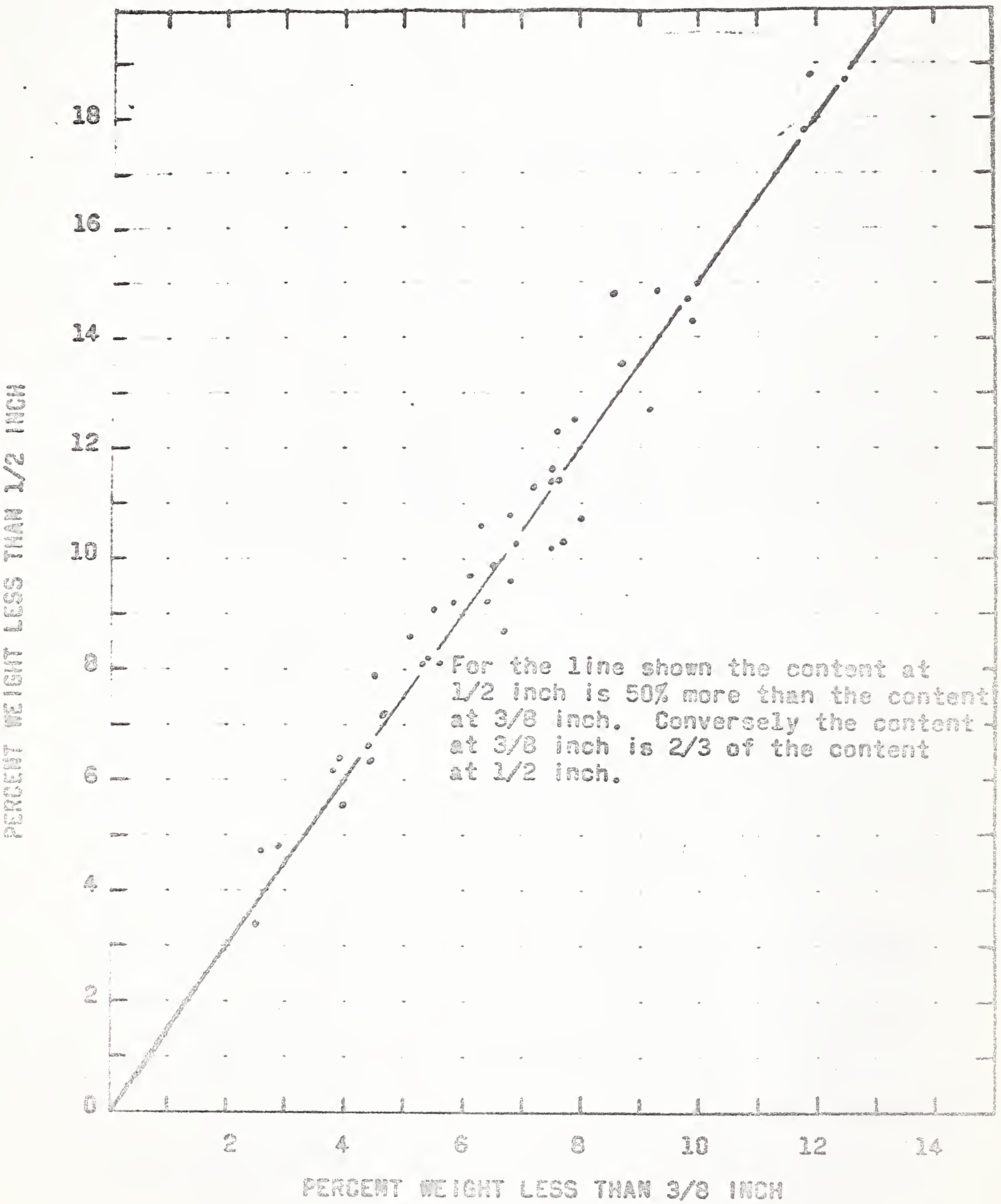
two measures is good and easily remembered.

Experimental Materials

The obtaining of cottons differing in short fiber content, while holding other valuable properties substantially constant, posed several difficulties. Two general techniques were used. One used the addition of cut sliver in varying degrees to cotton of inherently low short fiber content. The other technique used was differential ginning. Fortunately, the conclusions drawn on the effect of short fibers were the same for the two general techniques (5, 6).

The term differential ginning has been used recently to describe a ginning technique that produces cotton fiber samples having considerably different fiber distributions than those ginned in the conventional manner (2).

FIGURE 2. THE RELATIONSHIP BETWEEN SHORT FIBER CONTENTS AT 1/2 INCH AND 3/8 INCH UPPER LIMITS



In one experiment, handpicked Acala 44 seed cotton was ginned in five stages on a late model, standard saw gin operated according to manufacturers' recommendations except that weighed batches of seed cotton were hand fed into the roll box. After filling, the gin breast was engaged for 15 seconds.

A close inverse relationship between fineness and upper quartile length of fiber from a single lot of seed cotton was demonstrated. The effect of differential ginning in separating the available lint into lots of different length, Micronaire Readings, and short fiber content is depicted graphically in Figure 3.

Figure 3. The Effect of Differential Ginning by Five 15-Second Stages on Fiber Stages on Fiber Length, Short Fiber Content, and Micronaire Reading with Ginning Rate Superimposed

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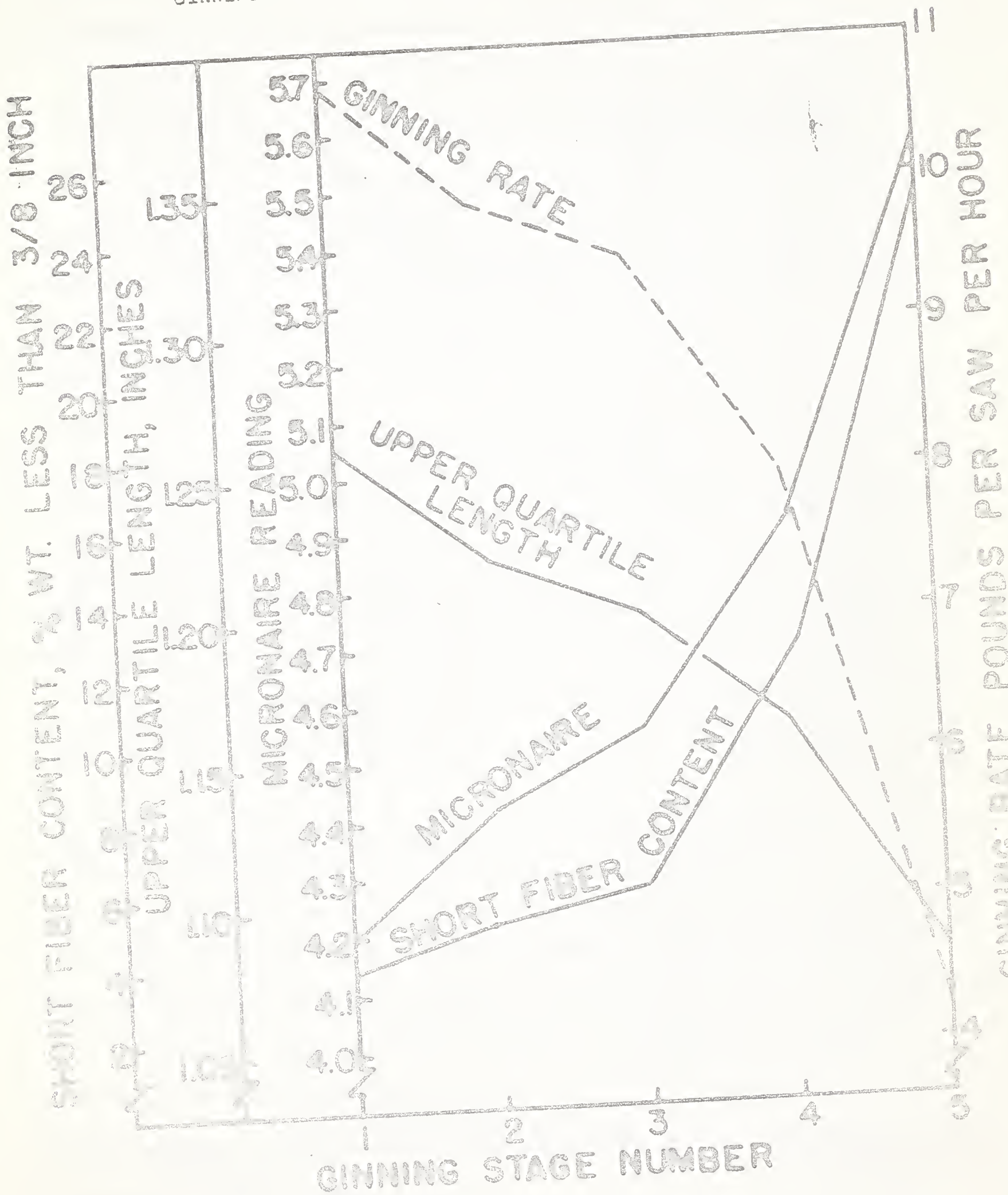
Ginning rate has been superimposed on these data to show the drastic change in rate as the number of ginning stages is increased.

It is significant that regardless of the seed roll weight which increased with each stage, the gin saws in each 15-second ginning period removed about 50 percent of the lint in the roll box. This efficiency level remained relatively constant while the per saw ginning rate decreased from a high of 10.7 to a low of 4.2 pounds per hour.

A limited investigation was made to determine whether the concept of random breakage as proposed by Byatt and Elting would explain the length distribution actually obtained (1). The results were negative. This is not too surprising, since the evidence indicates that differential ginning is not a random breakage phenomenon, but rather one of selective ginning.

FIGURE 3. THE EFFECT OF DIFFERENTIAL GINNING BY FIVE 15-SECOND STAGES ON FIBER LENGTH, SHORT FIBER CONTENT, AND MICRONAIRE READING WITH GINNING RATE SUPERIMPOSED



Further research to determine a satisfactory model for the length distributions obtained by differential ginning is needed.

Differential ginning appears technically feasible and represents a practical method of obtaining cotton with less than average short fiber content at the expense of producing other cotton with a greater than average short fiber content. The economic desirability of differential ginning has not yet been determined and must await additional experimentation and an economic analysis of its effect on the entire cotton industry.

Discussion of Procedure and Results

The cottons of varying short fiber contents were spun into a range of yarn sizes, from 14/1 (42 tex) to 36/1 (16 tex), and over a range of all practicable twists. Space permits the inclusion of only selected results; however, these are typical of the general findings.

The short fiber content versus single strand maximum tenacity is shown in Figure 4. The solid line was drawn to the observed data.

Figure 4. Single Strand Tenacity vs. Short Fiber Content for Acala 44 Cotton

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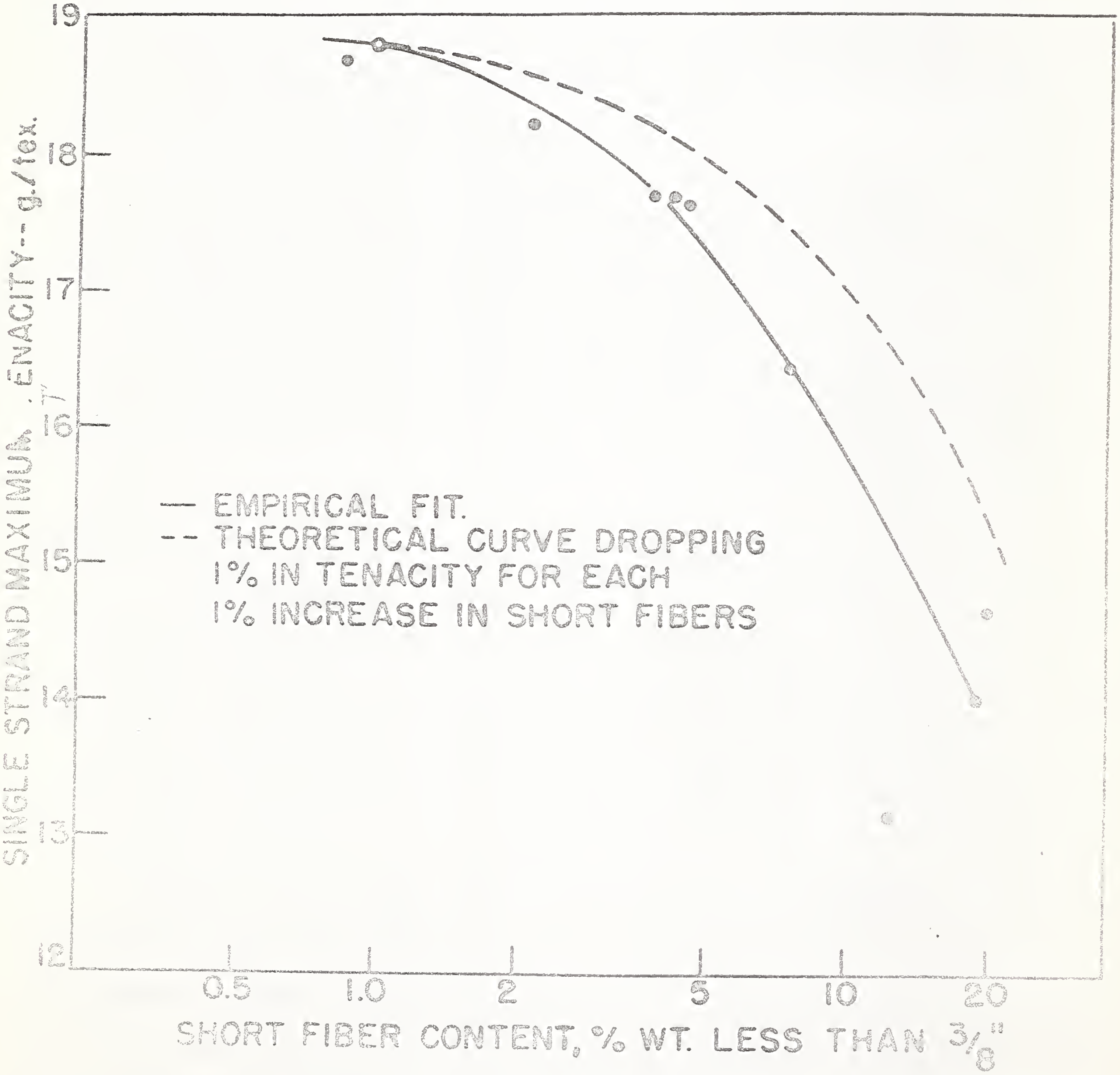
The dashed line is a calculated curve showing the expected decrease in yarn tenacity with increase in percent short fibers assuming the short fibers contribute nothing to yarn tenacity. (Coincidence was arbitrarily set at 1% short fiber content.) It can be seen that the actual decrease in yarn tenacity is greater than expected from such a simple hypothesis. The

FIGURE 4. SINGLE STRAND TENACITY VS. SHORT FIBER CONTENT FOR ACALA 44 COTTON



fiber tenacity for all samples was approximately the same when measured by conventional fiber bundle tests. The short fibers thus appear not only to add useless bulk to the yarn but also to prevent the working fibers from performing at their maximum potential. The effect is discernible even for small increases at low levels of short fiber content. Decreases in tenacity were greater in relation to increases in short fiber content than could have been expected if the assumption had been made that these fibers were merely inert weight.

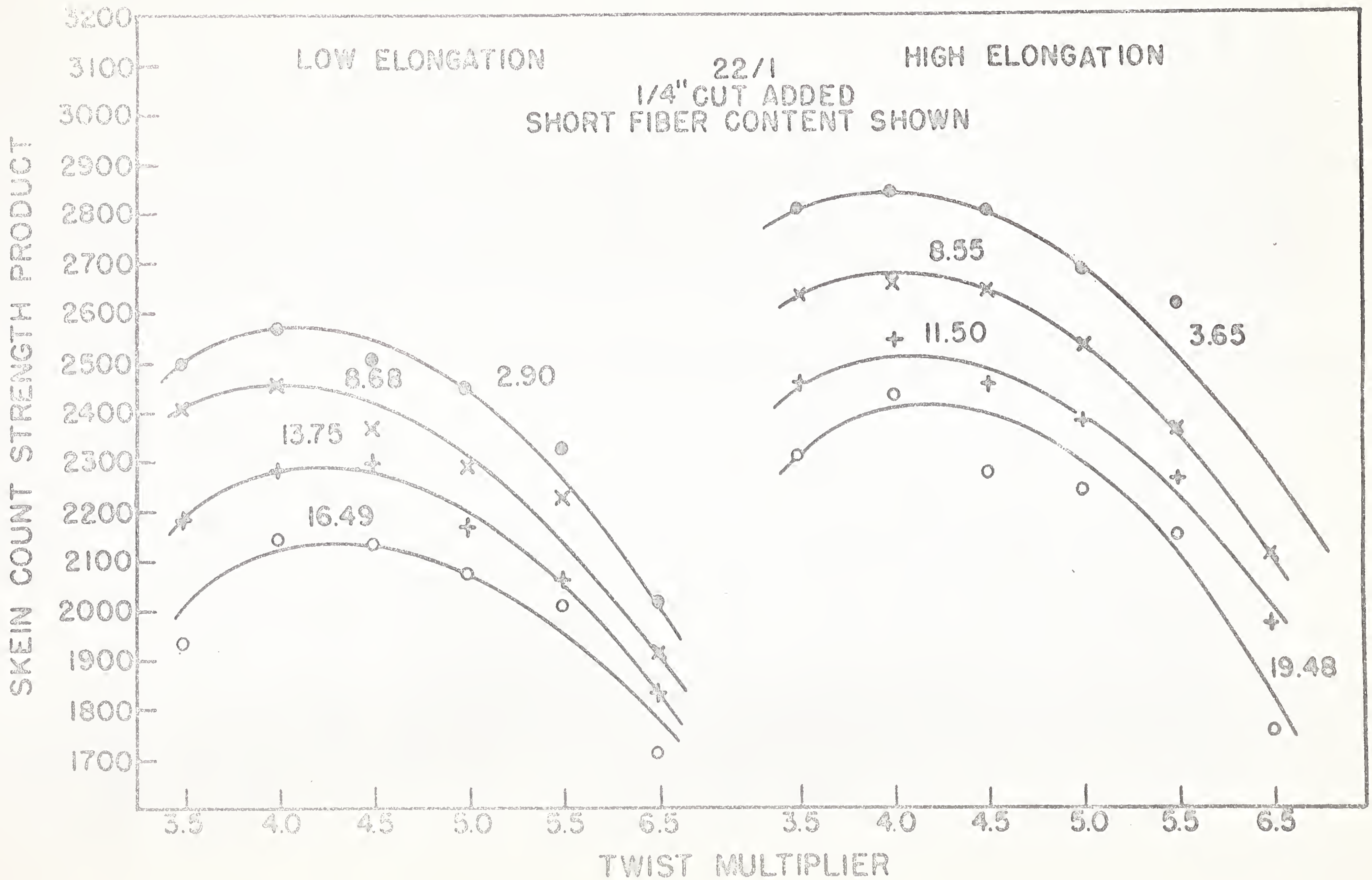
Short fiber contents, within the precision available for this determination, do not seem to affect the twist required for maximum yarn strength for a given upper quartile. Thus, it may be inferred that it is the longer fibers which determine the twist for maximum strength. Representative skein twist vs. count-strength product curves are shown in Figure 5 for the experiment in which cut sliver was added

Figure 5. Typical Twist vs. Count-Strength Product Curves for 22/1 Yarn, Showing the Effect of Addition of Short Fibers (1/4-inch cut)

to cottons of low short fiber content but different fiber elongation. It might be mentioned that there appears to be no interaction between fiber elongation and short fiber content with respect to the measured yarn characteristics.

Increases in short fiber content, probably because of increased unevenness, cause large decreases in yarn breaking elongation as well as breaking strength. These simultaneous losses appear more serious when it is recalled that the product of breaking strength and elongation is proportional to toughness or energy required for rupture. Thus, the yarns with the higher short fiber contents show a marked decrease

FIGURE 5. TYPICAL TWIST VS. COU NGTH PRODUCT CURVES FOR 22/1 YARN. SHOWING THE EFFECT OF ..DITION OF SHORT FIBERS (1/4 INCH CUT)



in toughness. This decrease amounts to almost 50% between yarns of the lowest and the highest short fiber content. It may be speculated that this effect would be considerably important in the utilization of such yarns in fabrics with resin treatments, which usually entail further strength and elongation losses.

While strength and elongation are very important from the engineering aspect, the appearance of the yarn may be of the major importance in many end-uses where esthetics play a large role. Table I

Table I. Yarn Appearance Grade as Affected by Short Fiber Content Over a Range of Twists and Yarn Numbers

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shows the yarn appearance grade over a range of twists and yarn numbers. The conclusion is that the short fiber content seriously degrades yarn appearance but that the deleterious effects may be mitigated by allocating the higher short fiber content cottons to the coarser, higher twist yarns. For example, if only C grade or above is acceptable, the 13% short fibered cotton may be utilized in the coarsest yarn at the highest twist while it requires the 5% short fiber cotton to produce the acceptable level for the finest yarn at the lowest twist.

One of the dominant properties associated with the utilization of cotton is the spinning performance available from a given lot of cotton. However, sufficient amounts of cotton often are not available to determine quantitatively the effect of short fibers on spinning efficiency since the measurement of this highly important property by spinning 5, 10, or more

Table I. Yarn Appearance Grade as Affected by Short Fiber Content Over a Range of Twists and Yarn Numbers

Nominal Short Fiber Content	14/1 Yarn			22/1 Yarn1/		36/1 Yarn		
	Twist Multiplier							
	3.50	4.50	5.75	3.50	4.50	3.50	4.50	5.75
% Wt. Less Than 3/8"								
5	B	B+	B+	B	B+	C+	B	B
8	B	B	B	C	B-	C-	C	C+
10	B	B-	B-	C+	C-	D+	C	C+
13	C-	C-	C	D	D	2/	D-	D
15	D+	D+	C	D	D	2/	D	D
19	D	D	D	2/	D	2/	2/	2/

1/ 5.75 twist multiplier not spun due to insufficient material

2/ Impractical to spin due to excessive ends down rate

thousand spindle hours is time consuming and requires quantities which often exceed those available in experimental cottons. Therefore, it was desirable than a shorter yet efficient procedure for determining the ends down rate be developed.

From the variance estimates of the previous experiments (9) it was indicated that where the data are recorded each 15 minutes, a three-hour run of about 720 spindle hours would allow the ends-down rate to be determined within ± 30% at the 95% confidence level (7). For cottons spinning outside the limits of approximately 20 to 150 ends down/1000 spindle hours, control chart "no-go" criteria were established to end the test after about 1/2 hour of spinning, thus conserving cotton and time.

To define the curve showing the effect of speed for a particular cotton at a particular yarn number and twist multiplier, at least three points on the curve were obtained. The experiment was accordingly planned to give at least two "go" tests and to increase speed on successive tests until more than 150 ends down/1000 spindle hours or a "no-go" test was obtained. This latter test might consist of as little as 120 spindle hours. No test was run at spindle speeds of less than 9000 rpm. The results are summarized in Figures 6 and 7 and show the

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Figure 6. The Effect of Spindle Speed on Spinning Efficiency for the Five Levels of Short Fiber Content - 30/1, 4.40 T.M.

Figure 7. The Effect of Spindle Speed on Spinning Efficiency for the Five Levels of Short Fiber Content - 40/1, 3.75 T.M.

FIGURE 6. THE EFFECT OF SPINDLE SPEED ON SPINNING EFFICIENCY FOR THE FIVE LEVELS OF SHORT FIBER CONTENT - 30/1, 4.40 T.M.

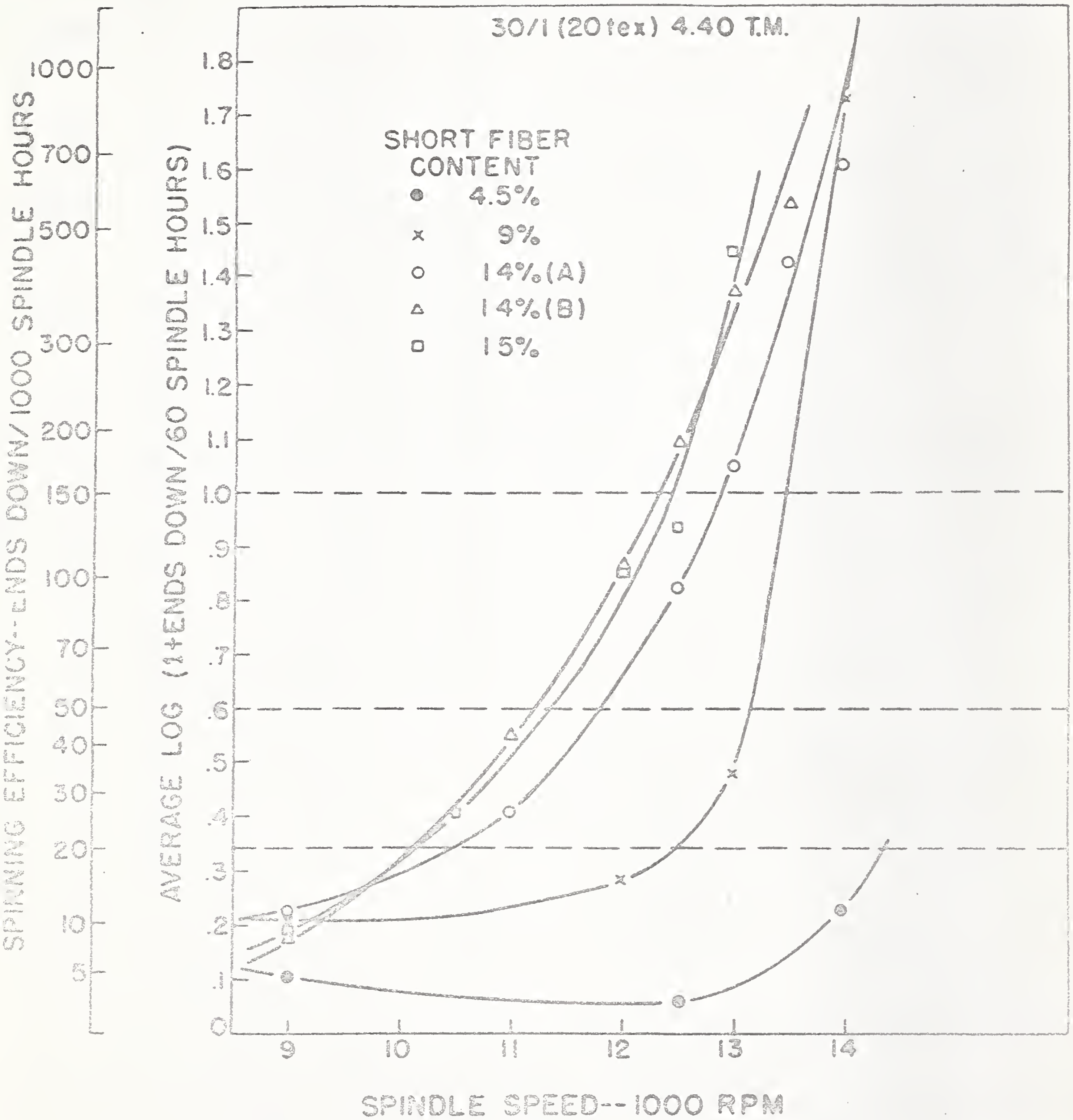
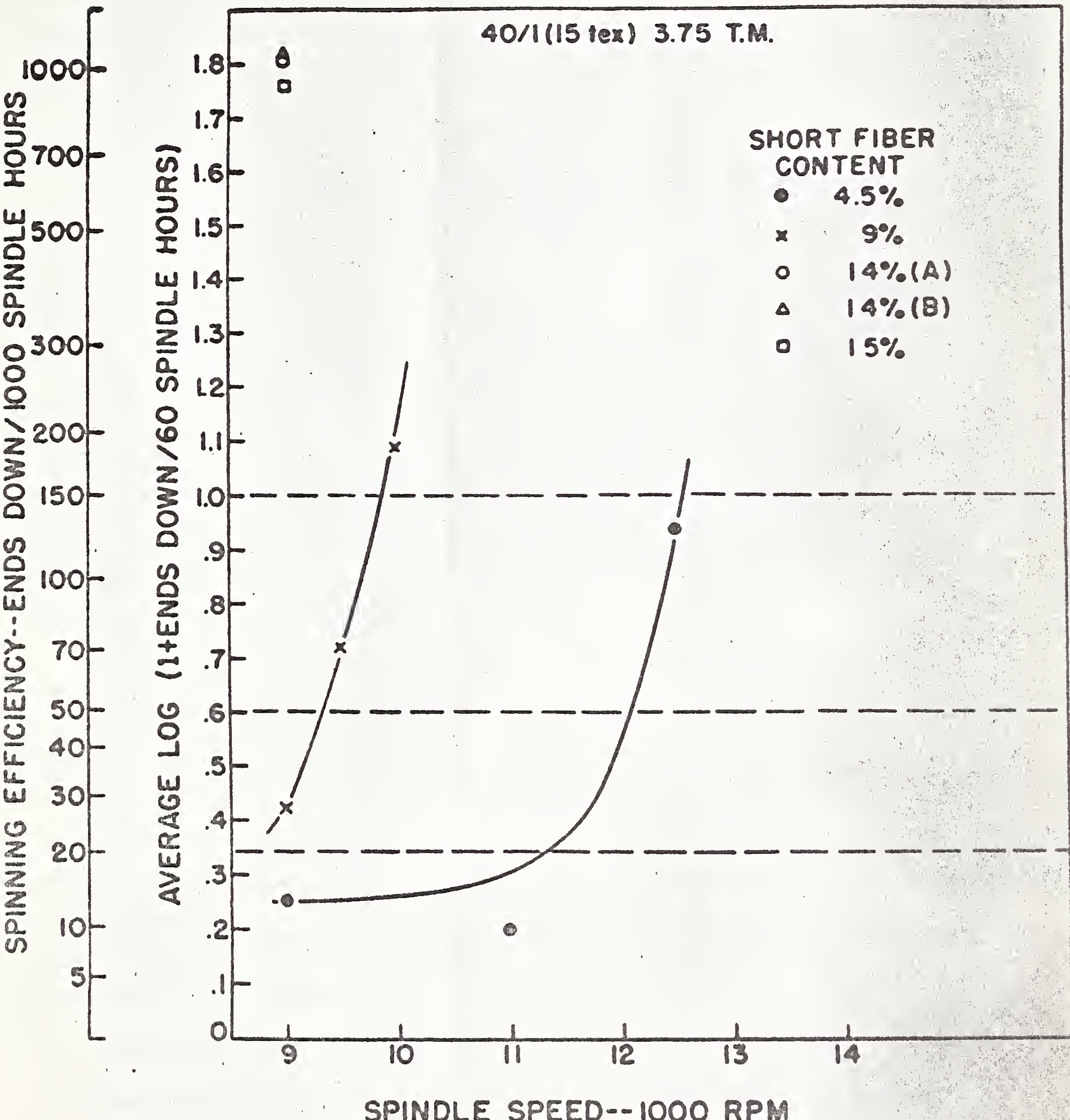


FIGURE 7. THE EFFECT OF SPINDLE SPEED ON SPINNING EFFICIENCY FOR THE FIVE LEVELS OF SHORT FIBER CONTENT - 40/1, 3.75 T.M.



marked effect of short fiber content and spindle speed on end breakage. The dotted lines at 20 and 150 ends down/1000 spindle hours indicate the approximate limits of the "go" region of the experimental procedure. The line at 50 is presented to aid the reader in taking intercepts at a reasonable level of spinning efficiency.

The ends-down rate for increasing short fiber content cottons is seen to become divergent as spindle speed is increased. Thus, for the 30/1, 4.40 T.M. yarn, all of the short fiber levels spun exceptionally well at 9,000 rpm; however, when spindle speed was increased, the end breakage rates of the yarns spun from the cottons with higher short fiber contents increased exponentially and rapidly became unspinnable, while the end breakage rate of the 4.5% cotton remained below the lower experimental design limit of 20 ends down/1000 spindle hours, even at spindle speeds of 14,000 rpm.

On the other hand, even at the low speed of 9,000 rpm, the three cottons containing over 10% short fibers could not be spun into 40/1 yarns at filling twist without impractically large end breakages.

While these experiments were conducted only on carded yarns, it seems probable that had the high short fiber content cottons been combed to reduce their level to approximately that of the low short fiber content cottons, comparable spinning performance might be expected.

Since most yarns produced are ultimately woven, it seemed desirable to investigate the effect of short fibers on fabrics (8). A typical 80 x 80 print cloth construction was used to obtain information on the effect that short fibers have on both grey and finished fabrics. Cottons varying in short fiber content from about 5% to 13%, but having other important fiber properties approximately equal, were processed into a print cloth, portions of which were bleached, mercerized, dyed and resin treated.

The data showed that increases in the short fiber content of either the constituent warp or filling yarns are detrimental to virtually all fabric properties. Furthermore, the detrimental effects of increases in short fiber content carry through all stages of finishing, including resin treatment. The magnitude of differences, for example, in the resin-treated state approximates that found in the grey state. Furthermore, there does not appear to be any significant "leveling" of yarn strength differences caused by variations in short fiber content when these yarns are carried into the grey or finished fabric state.

Not only were objectively determined values, such as strength, flex abrasion, and tearing strength adversely affected, but subjective qualities, such as appearance, smoothness, and hand were similarly degraded by increases in short fiber content.

These subjective properties may be of dominant importance in the utilization of a fabric in many end-uses, but unfortunately, such properties are not amenable to quantitative presentation and tabulation. Increasing short fiber content in either warp or filling yarn resulted in a degradation in general appearance and feel of the fabric in all treatments.

Conclusion and Summary

Where short fibers are defined as those fibers 3/8 inch and shorter and hence those not likely to break when the yarn ruptures, it appears that the following conclusions may be drawn.

1. Increases in short fiber content degrade yarn strength, both skein and single strand, yarn appearance, fabric appearance, and virtually all other properties.
2. Increasing levels of short fiber content, while decreasing the maximum strength available from a cotton, do not appear to affect the yarn twist required for maximum strength.
3. Spinning tests show that the relationship between spinning efficiency and short fiber content, for print cloth yarns (30/1 and 40/1), is complex and strongly influenced by spindle speed, yarn size, and yarn twist. Increases in short fiber content, in general, seriously decrease spinning performance. Further, it was found that once a cotton of a given level of short fiber content exceeds an ends-down rate of about 20/1000 spindle hours, end breakage increases exponentially with increases in spindle speed.

For a mill seeking to spin fine or low twist yarns at the maximum possible spindle speed the results obtained in this investigation point up the attractiveness of either (1) selecting cottons of low short fiber content initially, or (2) seeking means to reduce the short fiber content, which in the present state of the art would seem to mean combing. Also, for a mill spinning a diversity of yarn sizes and twists proper consideration of short fiber content and the allocation of appropriate cottons to the various mixes should increase overall spinning efficiency.

Furthermore, while almost 70% of the American Upland cotton crop is concentrated in the 1-inch to 1-1/16 inch staple lengths inclusive (10), care should be exercised in generalizing the findings of this series of investigations to other staple lengths. This is particularly true when considering absolute amounts of short fibers since "The percent of short fibers tends to decrease significantly as the staple length increases" (10). The important criterion in the utilization of any staple length cotton is not the percentage of short fibers but rather whether this percentage is excessive, normal, or low for a specific staple length.

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Discussion

Dr. Hertel: Did you change traveler size in spinning the yarns?

Mr. Tallant: No, the same size of traveler was used throughout the entire spinning for a given curve.

Dr. Heard: We went through 300 bales to find three bales which we used to make a short fiber content study. In brief, this is what we found on the 15/1 yarns:

Short fiber content	Yarn Strength	Clearer waste	Yarn appearance
5.5	high	low	good
11.0%	medium	medium	medium
17.0%	low	high	very bad

These results fully corroborate Mr. Tallant's findings.

Dr. Hertel: Are these cottons of the same length?

Dr. Heard: Yes, the staple lengths and all other pertinent fiber properties, except short fiber content, were the same for the three bales.

Mr. Barringer: In checking bales for short fiber contents, we have to check for true samples on both sides of the bales in order to avoid taking samples from "plates" in the bale and then take the average value.

BLENDING -- A MEANS OF MAINTAINING QUALITY IN COTTON PRODUCTS

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Changes in fiber properties as a result of new harvesting and ginning practices, coupled with the technical changes in mill processing techniques, such as high spindle speeds, use of larger packages, and the streamlining and condensing of prespinning operations, including the elimination of some operations, have increased the stresses on fibers and yarns during spinning. Demands on cotton fiber properties, *per se*, are being extended, since competition compels the textile industry to spin from a given quality of cotton the finest possible yarn numbers at highest spinning speeds and at twists commensurate with optimum production rate requirements. As a result, the short term cross-sectional uniformity of the yarns and the distribution of fiber properties within each unit cross-section are more critical factors of product quality and processing efficiency today than ten years ago. Development of one-process systems emphasizing drafts and de-emphasizing doublings and "sandwich blending" have caused serious departures from theoretical principles of blending. Also, technological advances in the preparatory processes of mixing, opening, and cleaning have not kept pace with the spinning processes. This has caused blending to become a somewhat haphazard operation dependent

on fortuitous conditions for fiber homogeneity rather than controlled blending principles; and has made it impossible to consider the "time-space" factor, wherein bales within a mix far apart in terms of rate of processing cannot be properly blended together.

To insure that the physical properties of the original raw fiber components are homogeneously distributed along a yarn, sound principles of blending must be applied at the raw stock stage, for most post-preparatory equipment, even newly developed, does not function as a "blender of fibers." On the contrary, the very principle of drafting tends to create unrandom distribution patterns, particularly if the fiber length distributions of a mix vary.

The only way then that cottons of contrasting fiber properties can be processed efficiently is to blend them **properly** as raw fiber components in the initial mix, so that the mass of fibers being fed to each succeeding processing operation contains representative amounts of each fiber property component. Blending also provides a basis for adjusting the levels of specific fiber properties needed to meet some specific performance requirement, such as strength, appearance, etc. Since the cotton crop will presumably continue to vary in fiber properties from year to year, area to area, and gin to gin, the textile industry should be placing more emphasis today, than in the past, on their blending practices, so that the reductions in the prices of textile products of 7 percent below the 1947-49 base period (4) can be maintained and possibly be reduced further.

This discussion proposes to provide impetus in this direction by (1) reviewing principles of recent developments in blending techniques; (2) giving theoretical reasons and experimental proofs why cottons of contrasting fiber properties can be successfully blended; and (3) presenting some speculative concepts of types of cotton blends which might be used successfully to meet some specific end-uses.

Practical and Theoretical Aspects of Blending

It is relatively simple to hypothesize that application of good blending principles results in homogeneous blends of fibers differing appreciably in fiber properties. However, to reach such a conclusion requires characterization of the fiber properties of component cottons of a blend in terms of individual length groups, rather than "averages", to see whether advantages accrue from blending, and whether fibers differing appreciably in fiber properties on an average basis can be blended efficiently to produce a blend of intended fiber homogeneity. In this connection, fiber fineness, length, and strength are chosen to illustrate that fiber populations of contrasting properties can be theoretically blended, and that when sound principles of blending are practiced, can be reproduced on a practical basis.

Blending by Fiber Fineness: Before examining what actually takes place in the blending of fibers differing in fineness, it is important to know the fineness distribution within a cotton fiber population for some representative cottons. Figure 1 (A) shows that for an average 4.0 µg./in.

Figure 1. Fiber Fineness Distribution Within a Cotton Fiber Population for Four Representative Cottons

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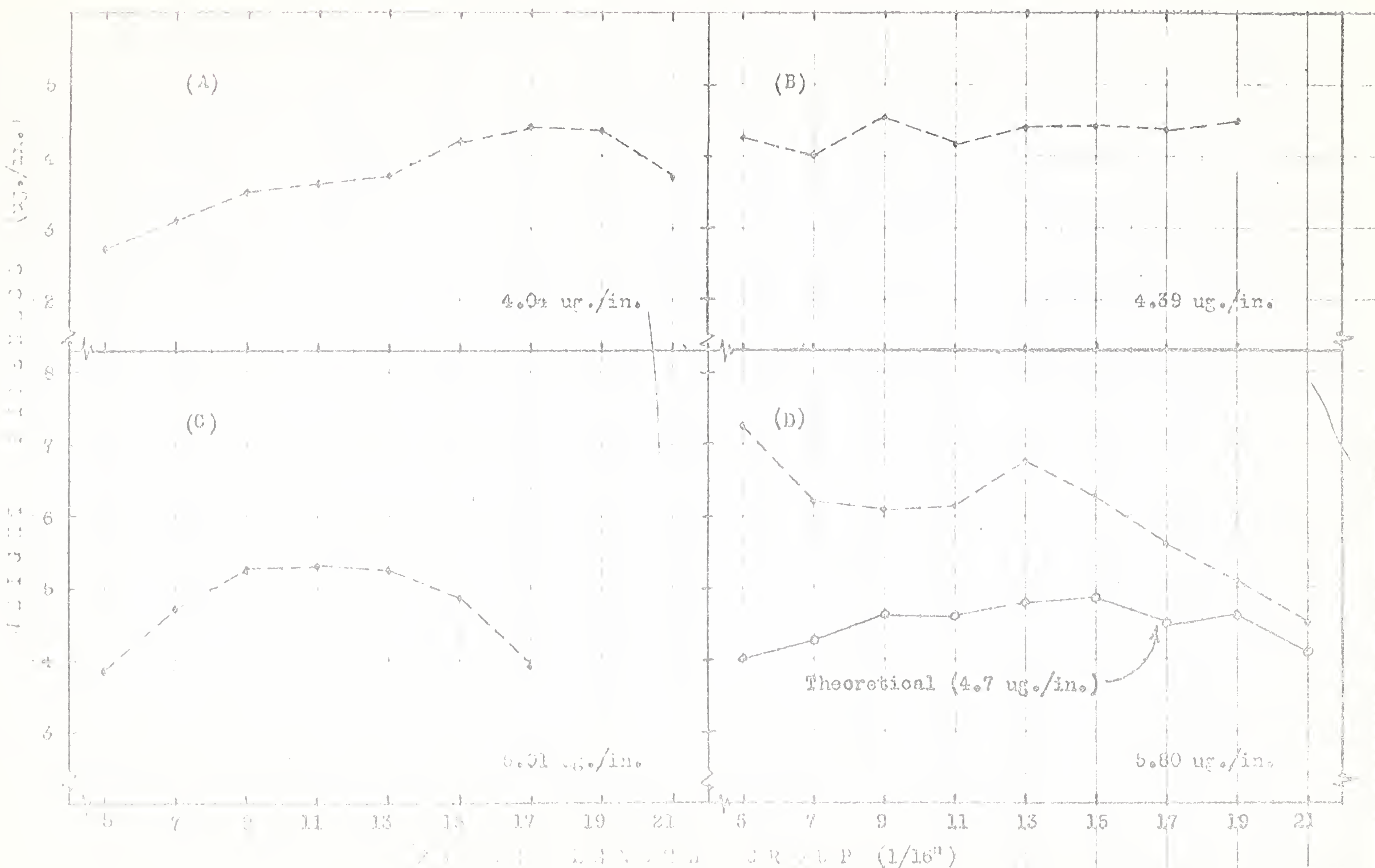
Figure 1. Fiber Fineness Distribution Within a Cotton Fiber Population For Four Representative Cottons



cotton the range of fineness is from 2.6 to 4.4 µg./in., with the longer fibers appearing coarser. Figure 1 (B) shows that the fiber distribution is very uniform for the different fiber length groups. Figure 1 (C) shows a cotton having a range of fiber fineness from 3.9 to 5.3 µg./in., and the coarser fibers occurring in the mid-fiber length groups. Figure 1 (D) shows that the shortest fiber group is the coarest, while the longest fiber group is the finest with a range from 4.5 to 7.3 µg./in., considered to be very wide. It is essential to recognize that even within a cotton sample population there is a great range in fiber fineness, and that the average fineness of a blend may easily reflect ranges in fineness of 100 percent.

In practice, the cottons represented by Figure 1 (A, B, C, and D) are blended together, and the theoretical fineness of the blend would be as indicated in Figure 1 (D) for the individual length groups, and also on an average basis. Obviously, an "averaging" effect takes place whereby extremes in fineness are reduced to where each length group has about the same value as the overall average of 4.7 µg./in. Of particular significance is that the extremes in fineness for the short length groups have been brought closer to the average, which from a practical standpoint showed no detrimental effects on the processing performance (5). Essentially, the composite blend of the four types of cottons has a fineness distribution population actually more uniform than an unblended cotton of the same average fineness (4.7 µg./in.). Therefore, theoretically the processing performance of the cotton blend made up of multiple fineness levels may be expected to be

at least equal to that of the unblended cotton, if the assumption is made that the blending technique used resulted in dispersing the different finenesses as homogeneously as in the unblended cotton.

To test this assumption, two cottons differing extremely in fineness (3 µg./in. and 6 µg./in.) were blended together resulting in an average fineness of 4.0 µg./in. The processing performance of this blend was then compared with that of an unblended 4.0 µg./in. "control" cotton. A parallel experiment was repeated by making up a blend with a resultant fineness of 5.0 µg./in. Its processing performance was compared with a "control" unblended cotton of 5.0 µg./in.

Figure 2 (A) shows the fineness distribution by fiber length groups

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Figure 2. Fiber Fineness Distributions by Fiber Length Groups of Blends of Fine and Coarse Cottons and Their Respective Unblended Controls

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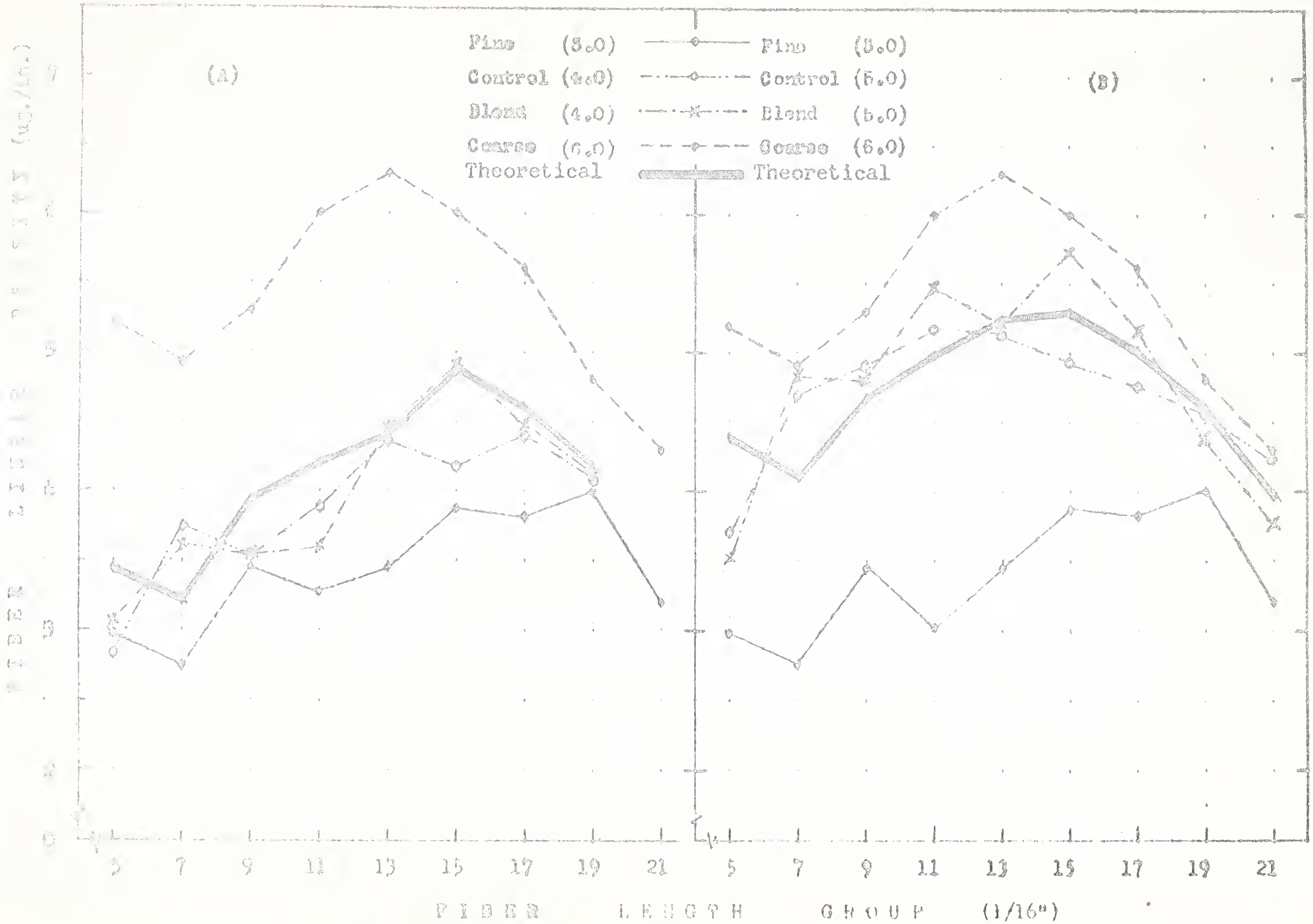
of a blended 4.0 µg./in. cotton resulting from a mixture of 60 percent and 40 percent fine and coarse cotton, respectively, and its unblended control cotton; while Figure 2 (B) shows identical data for a blended 5.0 µg./in. cotton resulting from a mixture of 75%/25% coarse and fine cottons, respectively, and its unblended control cotton (5). Also shown are the calculated theoretical (9) fineness distribution curves. In both cases, the fineness distributions resulting from blending fine and coarse cottons are practically identical to the distribution obtained from the control unblended cottons.

Figure 2. Fiber Fineness Distribution by Fiber Length Groups of Blends of Fine and Coarse Cottons and Their Respective Unblended Controls



Significantly, the theoretical distributions agree markedly well with the experimentally derived distributions, which proves when cottons of contrasting fineness properties are blended well the resultant fineness distributions can be made almost identical to the theoretical blend.

Figure 3 shows the nep formation data obtained during the carding

Figure 3. Nep Formation of the Controls, Blends, and Component Fine and Coarse Cottons (Basis: 30 lbs.)

of the controls, blends, and component fine and coarse cottons. For all practical purposes, the blended and control cottons in each fineness category produced card webs of similar nep content to respective controls on an average basis for the stripping cycle.

When a coarse cotton of low nep potential is blended with a fine one of high nep potential, nep formation is approximately proportional to the percentages of the component cottons in the blend (12). Also, the blends did not have higher nep formation potential than the controls.

Figure 4 shows skein count strength product plotted as a function of

Figure 4. Effect of Blending Cottons Differing in Fineness on the Skein Strength of Single Yarns of Varying Twists (Average Fineness 4.0 µg./in.)

twist for coarse and medium yarns spun from the control, blended 4.0 µg./in., fine and coarse cottons. The twist strength curves for yarns spun from the control and blended cottons are similar in all respects. Importantly, the same twist is required to obtain maximum strength in the control and blended yarns, even though yarns made from the blended cotton contain fibers varying

Figure . Nep Formation . the Controls, lends, and Component Fine and Coarse Cottons (Basis: 30 lbs.)

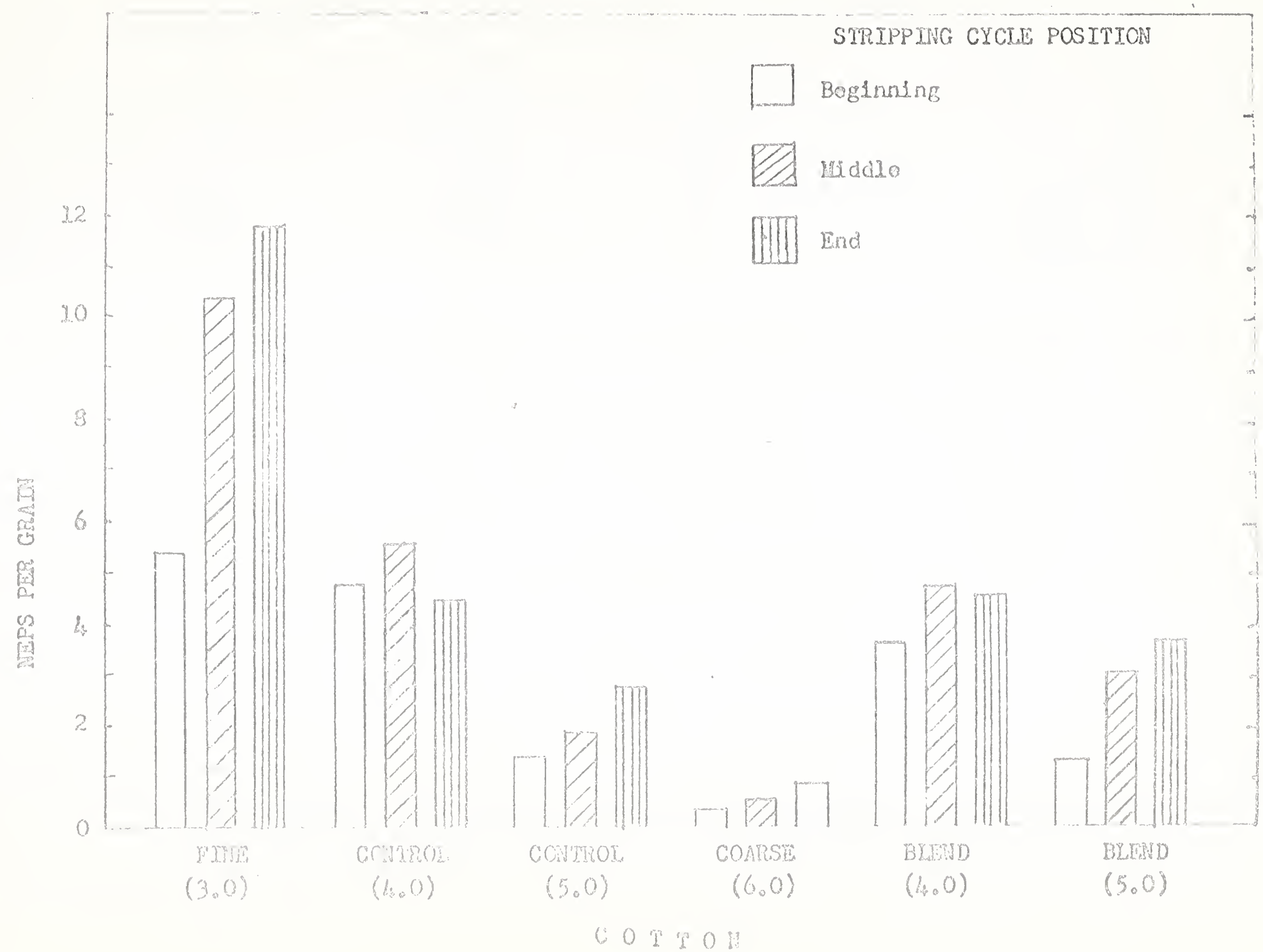
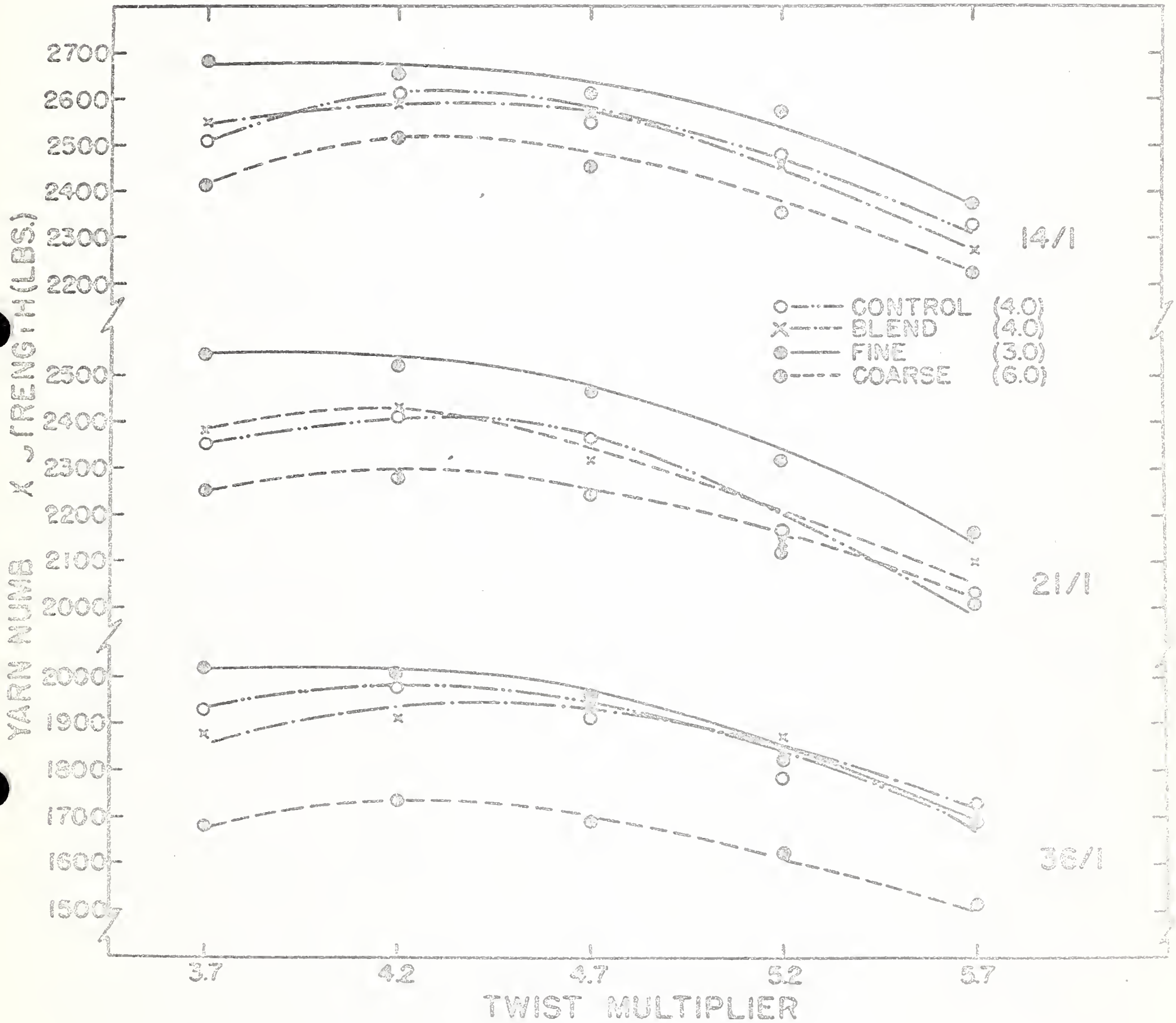


Figure 4. Effect of Blending Cottons Differing in Fineness on the Skein Strength of Single Yarns of Varying Twists (Average Fineness 4.0 ug./in.)



extremely in fineness. Also, the low yarn strength resulting from coarse fibers is offset by the addition of fine fibers as illustrated by similar strengths between yarns made from the blended and control cottons. These conclusions are true for all the yarn numbers evaluated.

When blends averaging 5.0 µg./in. are made, as in this study, the percentage of coarse fibers in the blend exert an adverse effect on yarn strength as illustrated in Figure 5. These data clearly indicate that

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Figure 5. Effect of Blending Cottons Differing in Fineness on the Skein Strength of Single Yarns of Varying Twists (Average Fineness 5.0 µg./in.)

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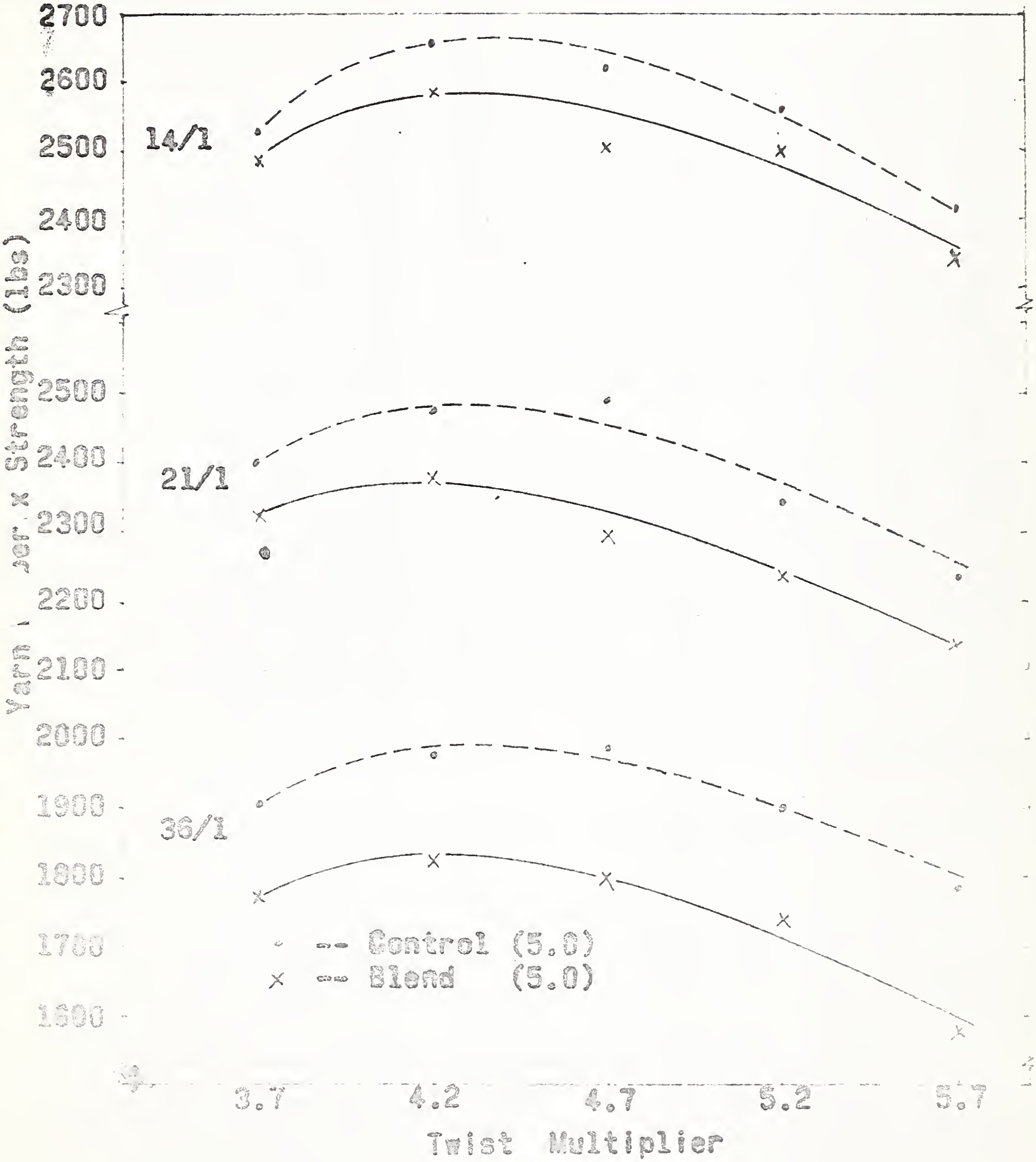
the strength of yarns made from the blended 5.0 µg./in. cotton was significantly lower than yarns made from the control for all twists and yarn numbers.

This demonstrates the percentage (by weight or by fiber number) of fiber components in the blend is of utmost importance. In this case, there was not enough fine fibers in the yarn to offset the stiffer, coarse fibers during twisting and binding. Strength differences increased between the control and the blend as the yarn became finer, which indicates that not only the ratio of fine to coarse fibers affects yarn strength, but also the number of fibers in the yarn cross-section. Data from Figures 4 and 5 prove that cottons differing extremely in fiber fineness can be blended satisfactorily when the average fineness is about 4.0 µg./in., but that as the average increases the adverse effect of the coarse fibers becomes evident. Based on these data, it is postulated that for yarn numbers 36/1 (16 tex) and finer, the fine and coarse fibers used to make up the blend should not have a resultant average fineness of much over 4.0 µg./in.

Figure 5. Effect of Blending Cottons Differing in Fineness on the Skein Strength of Single Yarns of Varying Twist (Average Fineness 5.0 ug./in.)



Furthermore, in yarn manufacturing the properties of fibers are translated into yarn properties in the form of bundles. As the yarn becomes finer, the number of fibers per yarn cross-section diminishes, and the probability of obtaining a true representation of component fibers in the yarn decreases. In other words, for example, the chances of finding a true average fiber fineness in a fine yarn is much less in comparison with a coarse yarn spun from the same blend. Additionally, the greater the number of components in the blend, the lesser is the probability for each component to occur in some random order in a given fine yarn cross-section.

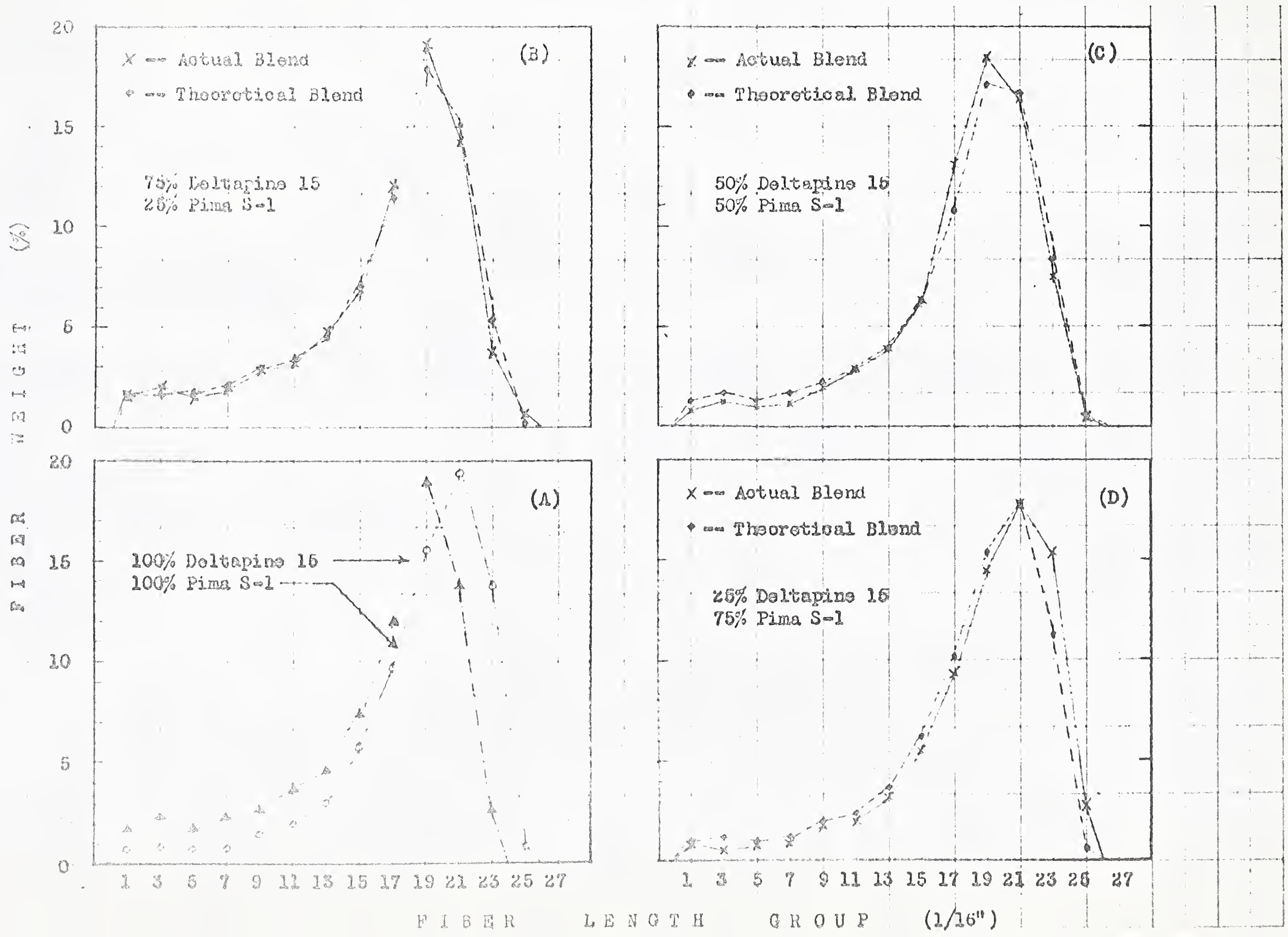
Blending by Fiber Length: It has been shown that the fiber length distribution of a cotton exerts an important influence on both processing efficiency and product quality (13). It should be of extreme interest and importance to see whether a specific fiber length distribution can be made by blending cottons differing widely in length properties and whether the advantages of long cottons are retained when blended with shorter cottons.

Figure 6 shows results from blending two cottons (Deltapine 15 and

Figure 6. Comparison of Fiber Length Distributions Between Actual and Theoretical Blends at Various Percentages of Deltapine 15 and Pima S-1 cottons

Pima S-1) differing in fiber length and length distribution at various percentages by weight on a small scale table model blender. Figure 6 (A)

Figure 6. Comparison of Fiber Length D' trit ons Between Actual and Theoretical Blends at Various Percenta nds of Deltapine 15 and Pima S-1 Cottons



shows the fiber distributions of the two component cottons. Figure 6 (B), (C), and (D) compare the fiber length distributions of the actual blends of Deltapine 15 and Pima S-1 in proportions of 75%/25%, 50%/50%, and 25%/75%, respectively, with the theoretical blends based on the mathematical averages of the component curves in Figure 6 (A). These data prove that, if properly done, one can blend cotton fiber length to a projected fiber distribution. Table I shows the pertinent fiber length properties of the component and

Table I. Comparison of Fiber Length Properties of Deltapine 15, Pima S-1, and Selected Blends of These Cottons

blended cottons. Except for the obvious sampling and/or experimental error in the 25%/75% blend, the upper quartile length, mean length, fibers of 3/8" or shorter and coefficient of variation of the blended lots show progressive improvements with increased percentages of Pima S-1 cotton.

Since cottons of longer staple length usually have less short fiber content (7), and short fibers are immature, fine and weak (6), reduction of any amount of short fibers from the fiber population would surely increase the spinning efficiency of the cotton. At present reducing short fiber content through actual extraction is economically infeasible. The alternative is through blending, therefore, because by selective blending, as illustrated, one can obtain a blend having desired fiber length distribution, as well as improve the fiber length properties of the existing cotton.

Modern long drafting equipment is relatively insensitive to length differences, so the inclusion of long fibers in a blend should not seriously affect mechanical processing organizations.

Table I. Comparison of Fiber Length Properties of Deltapine 15, Pima S-1, and Selected Blends of These Cottons

Fiber Length Properties1/	Deltapine 15 Pima S-1	100% 0	75% 25%	50% 50%	25% 75%	0 100%
Upper Quartile Length (in.)		1.23	1.25	1.28	1.37	1.34
Mean Length (in.)		0.97	1.02	1.06	1.16	1.14
Fibers of 3/8" or Shorter		6.03	5.25	3.23	2.11	2.31
Coefficient of Variation (%)		35	33	28	26	25

1/ Fiber length properties measured from raw stock cotton processed through a small-scale table model blender.

Blending by Fiber Strength: Another critical criterion of quality textile product is fiber strength. Figure 7 (A) shows that the flat bundle breaking strength of a blend composed of 50 percent strong and

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Figure 7. Actual and Theoretical Blending of Cottons Differing in Fiber Breaking Strength

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50 percent weak cotton fibers is about the mathematical average of the two components (12). Similar observations may be noted for the 75%/25% and 25%/75% blends. By the same principle, e.g., blending a Rowden and Wild 13 cotton (6) in a 50%/50% proportion would result in a cotton blend with a resultant strength represented by the dotted line as shown in Figure 7 (B). Yarn data shown in Figure 8 were obtained from yarns spun from the five

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Figure 8. Effect of Fiber Bundle Strength and Spinning Twist on the Skein Strength, Single Strand Yarn Strength and Breaking Elongation of 36/1 Carded Yarn

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cottons shown in Figure 7 (A) and are designated by their respective fiber bundle tenacities in terms of grams/tex. Yarn strength increased in proportion to the percentage of stronger fibers in the blend, and this trend holds true in finished fabrics, except resin treated. This illustrates that through proper blending any desired average level of fiber strength can be obtained and translated into stronger yarns and fabrics.

Problems and Practices in Blending

Probability of a "Perfect" Blend: Theoretically, if sufficient doubling and blending are made, one can obtain a blend of fibers which

Figure 7. Actual and T oretical Ble , of Cotton Diffe g in Fiber Breaking Strengt

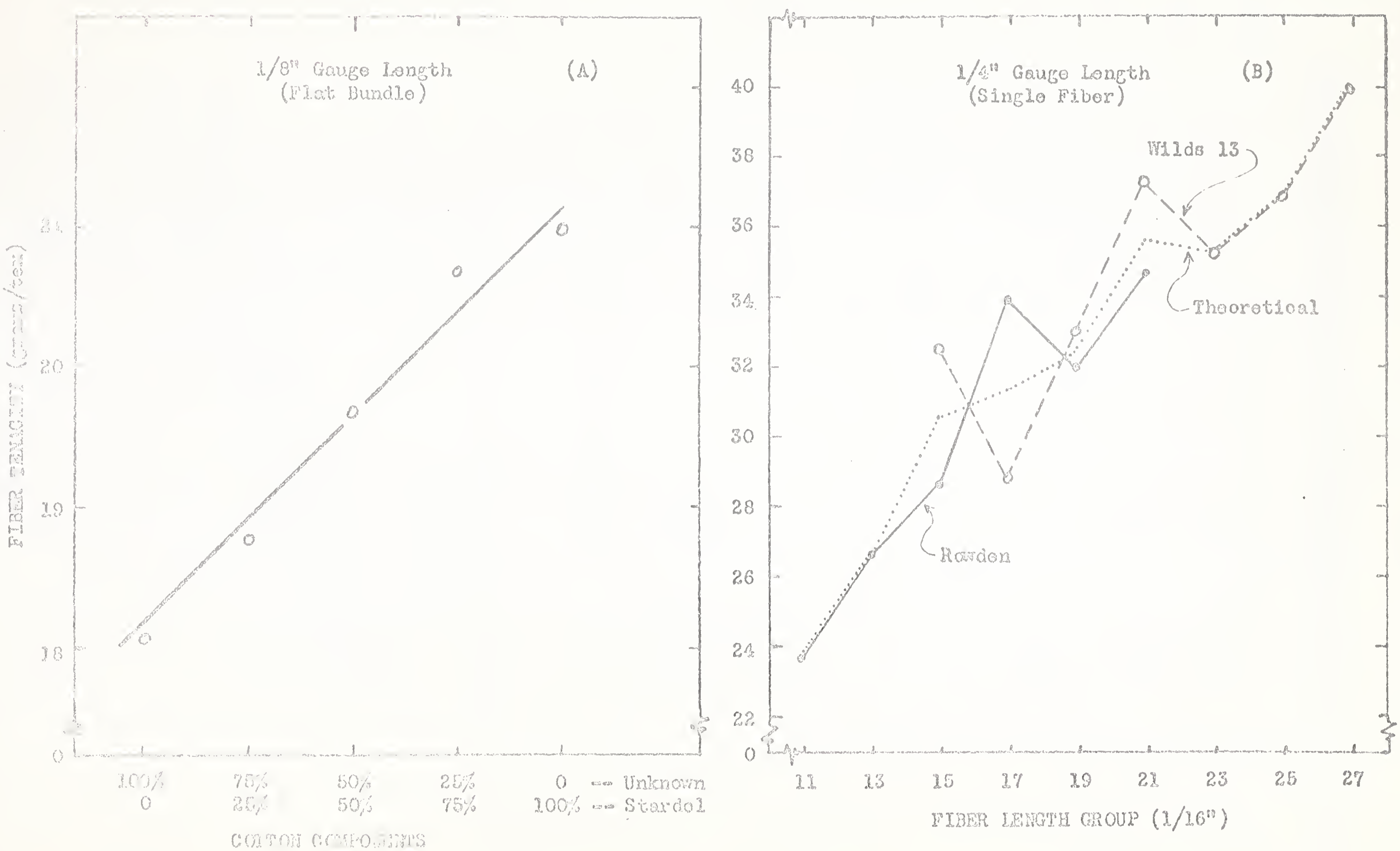
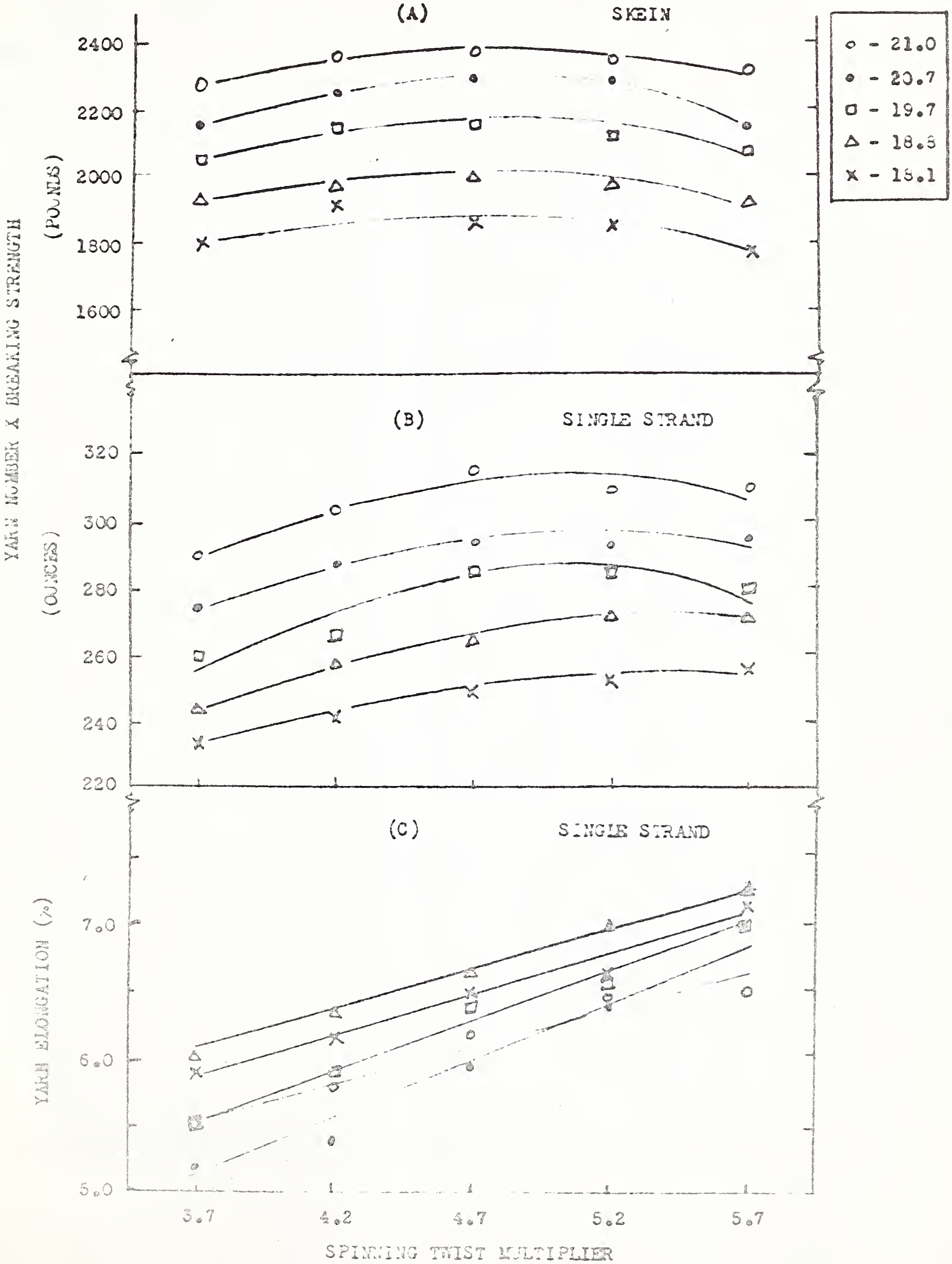


Figure 8. Effect of Fiber Bundle Strength and Spinning Twist on the Skein Strength, Single Strand Yarn Strength and Breaking Elongation of 36/1 Carded Yarn



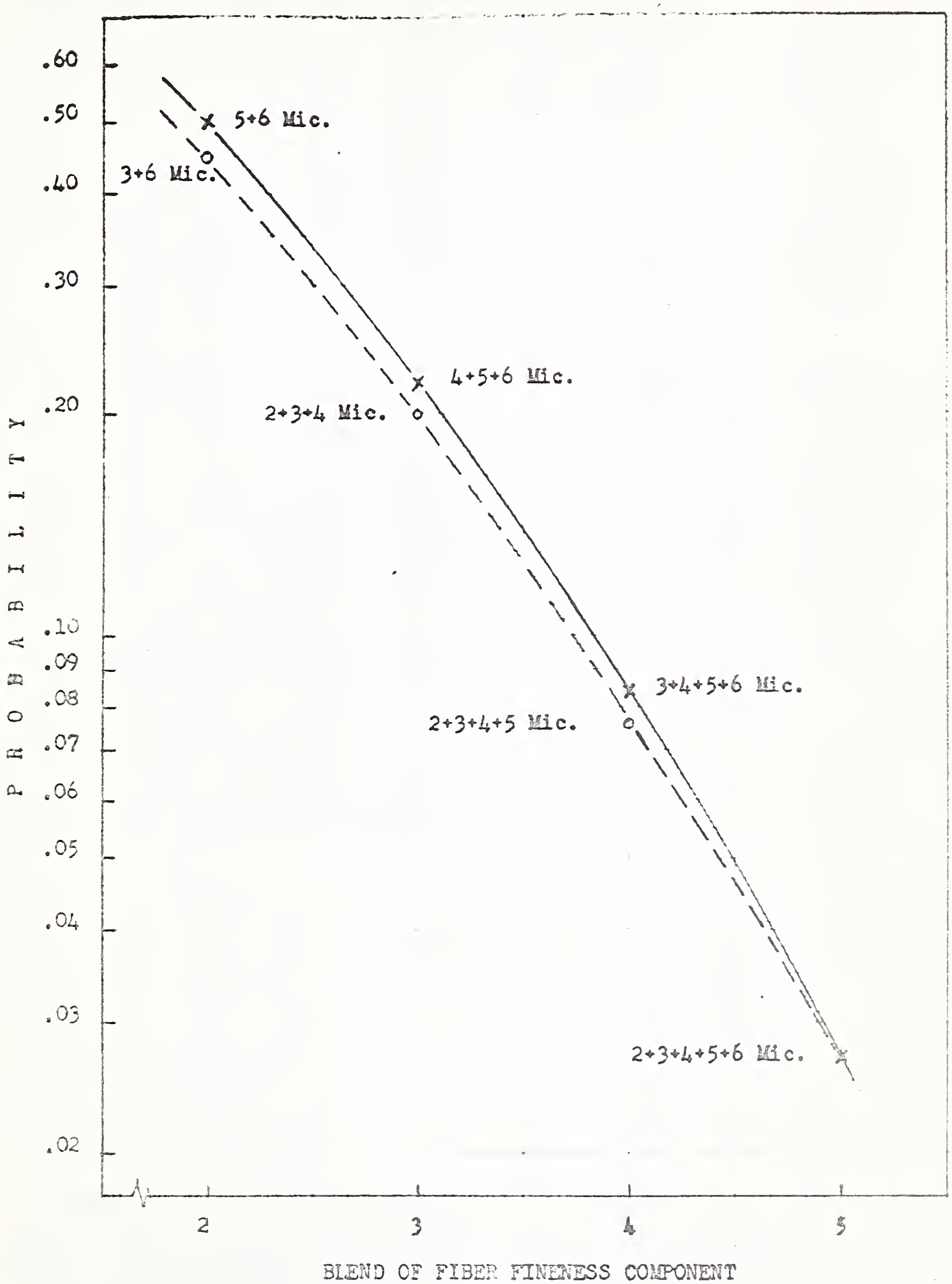
are randomly distributed in the specified percentages of the raw material components. Figure 9 shows the probabilities of obtaining such a "perfect"

Figure 9. Probabilities of Obtaining a "Perfect" Blend for Various Combinations of Fiber Fineness Components of Equal Weight

blend in a nonflow hopper for various combinations of fiber fineness components. In the extreme case where one unit weight of 2, 3, 4, 5, and 6 μg./in. cottons are blended in the hopper, the chance of drawing five fibers simultaneously from the hopper to represent each of the five cottons is about 3 out of 100. As the components used in the blend decrease, the chance for a "perfect" blend increases in a semi-log scale. The probability of obtaining a "perfect" blend decreases when different weights of the component are used. This chance is further lessened in actual operational conditions where cottons in the hopper are continuously fed to a conveyor belt. Therefore, the chance for obtaining a "perfect" blend in mill conditions is remote. To improve the probability of obtaining a "perfect" blend, it is necessary, therefore, to have a thorough knowledge of the principles and mechanics of blending.

Size and Density of Raw Materials: One of the critical factors in blending is the size of the raw material fed into the hopper feeder. For example, consider a food blender jar half filled with an equal number of red and yellow beans of the same size. Shake the jar well and one will find that the red and yellow beans fairly well disperse among each other. Divide each bean in half, put them back into the jar and shake again; one would find the degree of mix is greatly improved. Ultimately, when the

Figure 9. Probabilities of Obtaining a "Perfect Blend" for Various Combinations of Fiber Fineness Components of Equal Weight



beans are granulated into fine grains, the original red and yellow beans will blend into a homogeneous orange-colored mix. A similar observation may be drawn from cotton blends of different size tufts. Furthermore, big tufts of cotton have lesser mobility than smaller tufts within a given confinement. Also, greater work is needed to overcome the internal friction which holds the fibers together in order to tear the big tufts into a small workable size. As a result, small tufts will blend much easier and better than big tufts.

Once the cotton tufts are in a duck conveyor system, uniformity of size becomes extremely critical, for aerodynamically, different size tufts will travel at different rates; hence, they will arrive at the condensing unit in an entirely different order than originally blended. The hopper feeder should be fed small cotton tufts, so that it, in turn, can deliver uniform aggregates to the next processing operation. It is against all good blending practices to feed the hopper feeder large "slabs" of cotton from the bale, for the feeder is not designed to break the large pieces into small tufts with equal efficiency for cottons of different fiber properties or densities. If this practice of "slab" blending is allowed to continue, all the careful planning of the "original" bale mixing plan will be lost right at the beginning of the preparatory processes.

Another problem in blending is the density or compactness of the raw material in the hopper feeder. The rate of feed, size of material fed, and the density of the bales affect the density of the material in the hopper feeder, which, in turn, influences its feeding rate to the next operation. It has been reported (2) that fiber fineness affects the density of raw material in a hopper feeder to such an extent as to cause

the fine fibered cotton to be fed relatively faster than the coarse fibered cotton. Preferential feeding of fine and coarse fibers, though unintentional, in the hopper feeder defeats the very intent of the original bale mixing plan, and considering that fineness is one of the most important contributing fiber properties, the resultant adverse effects on both product quality and processing efficiency are self-evident.

Blending by Volume: Except for a few recently improved blending systems, most existing blending equipment uses the principle of volume feeding. With this system cotton is fed into a hopper feeder having a storage bin of constant capacity. It is assumed that (1) the height of the cotton in the hopper will be kept at a constant, resulting in constant volume; (2) the density of the cotton is constant; and (3) the rate of feed is constant for all fiber components and for the overall mass of cotton. In actual practice these conditions are met rarely; that is, in the first two instances the volume and density of cotton in the hopper are subject to operator influence, which can be considerable, and in the third instance spiked aprons and stripping combing rollers are not designed or suited to maintain constant weight feeding from a cotton source of varying density. Volume feeding has the further disadvantage of allowing the "time-space" problem to get out of control, since operators rarely will feed samples from every bale in the mix. For example, the middle portion of the bales feeding the tenth feeder never catch up with the top portion of the bales feeding the first feeder, since the sandwich formed is constantly being delivered in the cross-sectional direction to the next operation. Paradoxically, the efforts used to measure fiber properties, categorize cotton bales according to properties, and layout of suitable mixing plans may all be nullified merely due to volumetric blending.

Blending by Weight: In this case, the hopper feeders are equipped with automatic weight-pans which regulate the weight of the stock fed from the feeder. Since cotton bales of different fiber properties are blended initially on a weight basis, it would seem logical to preserve the originally assigned weight ratios in the mix, at least through the first critical process of mass feeding by having a weight controlled delivery system (10, 14). The weight-pans discharge the stock simultaneously at predetermined intervals to a sandwich forming common conveyor belt, which continuously feeds the stock for additional blending and onto opening and preparatory equipment.

To really operate this system efficiently, small tufts of cotton should be fed to the hopper feeder, resulting in constant density of the cotton. Since the number of doublings and the bin capacity are limited to less than ten hopper feeders, there is a possibility that this system may fail somewhat in covering the "time-space" factor, especially when a large number of bales are used in the mix, since beyond the feeders there is no opportunity for massive doublings.

Blending by "Sandwich" Technique:

Simple Sandwich: This system represents conveyor belt arrangements which receive layers of cotton from a series of hopper feeders whether it is volumetric or weight controlled. It is basically a good system, but lacks the consideration of the "time-space" factor, since it feeds into a continuous one-process preparatory system.

Multiple Sandwich: This system employs massive doublings and controlled accumulation of raw material many times greater than other

sandwich blending systems. In this case the doublings take place after the hopper feeders, so that even though the component raw materials are far apart from one another in time and space, they can be brought together in the blending bin. Further blending takes place by having the multiple layers of blended raw stock cut through conventionally in "sandwich" fashion and delivered to the next operation. Essentially, this system eliminates the "time-space" problem. If this system if fed volumetrically, its advantages may be minimized, since it is positioned far away from the original bales and the hopper feeders.

Blending by Preblending: To mask out differences in fiber properties among bales, and to a certain extent within bales, the practice of blending large numbers of bales, and then rebaling them, has been started both at the merchant (7) and mill (8) levels. This technique has been called preblending and has the unique advantage of automatically taking care of the "time-space" factor once the rebaled cotton is laid out in some orderly mixing plan prior to being fed to the hopper feeders. Preblending has the distinct advantage of collectively "averaging" out all the fiber properties, so that when the blended bales are used in the mix at the hopper feeder, fiber properties are represented by averages which vary much less among bales than in the original bales prior to preblending. This low variation in the average fiber properties among bales automatically reduces some of the objectionable influences of operator bias and volumetric feeding.

Preblending requires relatively costly equipment and large working areas. Each mill must decide for itself whether the investment is worth

the advantage of being able to use less costly cottons in its mix. An ideal preblending system should (1) include large numbers of bales to take care of the "time-space" factor; (2) use the principle of "blending by weight"; (3) break up the cotton into tufts of consistent density; and (4) use a minimum of clearing equipment (none, if possible) to avoid fiber damage.

<u>A Specific Blending Technique</u>: A unique technique of massive blending (3) worth mentioning is characterized by its operational simplicity, use of conventional equipment, and its claim of obtaining absolute fiber homogeneity even in blending cottons of extreme properties. One hundred to 200 bales of cotton are staggered in rows from full to about one-quarter full throughout a spacious room. Several operators with trucks take small tufts from each bale and place the cotton onto a long lattice conveyor apron, which feeds into an automatic feeder, opener, and then a breaker picker. Full bales replace the one-quarter bales as they deplete, so that at all times the entire lot remains in a staggered position. The breaker picker laps are lined up in stacks of 40 to 60. From four to six breaker laps are then taken from stacks, according to a statistical pattern designed to insure having representative samples from all of the 100-200 bale mix, and processed into finisher laps, placed in stacks of 40 and fed to the cards according to a statistical pattern, assuring maximum blending of the original bales of cotton. This system does not represent a continuous flow of material from raw stock through finisher picker lap as practiced in this country.

Nevertheless, by virtue of its discontinuity at the breaker lap stage, it satisfies the basic principles of ideal blending and permits use of low cost cotton qualities, differing appreciably in price, in mixes, and end-uses usually considered impractical and impossible in this country.

Summary

Blending cottons of contrasting fiber properties, using as blending components fiber fineness, length and strength, has been shown to be theoretically possible. Specific requirements for obtaining fiber homogeneity are (1) the feeding of small cotton tufts of about equal size to the hopper feeders; (2) constant density of the cotton mass in the feeders; (3) feeding by weight rather than volumetric principles; and (4) arranging the mixing plan to take care of the "time-space" factor. Following are some suggestions which may be of assistance in blending by allowing the use of cottons of more contrasting fiber properties and also of lower grade than are being used now for certain end-uses:

1. Segregate cottons which differ extremely in properties, particularly fineness, so that they will feed to separate feeders. This will prevent preferential feeding.

2. Feed small cotton tufts similar in size to the hopper feeders so that the disadvantages of volumetric feeding may be minimized. Never feed large slabs of cotton from the bale.

3. Maintain constant density in the hopper feeders by keeping the hopper bin filled to a constant height.

4. Use discretion when a "waste" feeder is in the line, particularly

when card strip waste - containing essentially short fibers - is fed to the system. Since the amount of waste is relatively small in proportion to the rest of the mix, intermittent feeding may be necessary, resulting in an uneven distribution of short fibers in the laps and yarn. To minimize the problem of waste feeding, the waste can be first mixed with some raw cotton and then the resultant sub-mix can be used as part of the master mix. In the event small amounts (10% or less) of off-grade cotton is used, a similar technique may be employed to obtain better blending.

5. Use weight in place of volumetric feeding principle. Since this involves changes in equipment, an alternative approach might be to provide a break somewhere in the preparatory line, such as the finisher picker, to provide for additional doubling, which in essence introduces a weight control process. This could mean reverting to the old system of blending breaker laps.

6. Exercise more control over blends as the yarn number becomes finer. Product quality and processing efficiency react more critically to reduction in fibers per cross-sectional area and the distribution of the properties of component fibers. This observation probably is applicable also to yarns of lower twist, because the adverse effects of non-random fiber distribution may be compounded due to the added disadvantage of less binding power of the fibers. It would appear that a weight controlled blending system is almost mandatory for manufacturing finer yarns.

7. Preblend cotton with a minimum of equipment, if economically possible, for there appears to be no theoretical disadvantages since this operation levels out extremes in fiber properties. For fine yarns preblending has advantages, but it is problematical whether the same advantages are realized for coarse yarns.

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Discussion

Mr. Blomquist: Did you do any work to compare the difference between volume feeding and weight feeding?

Mr. Fiori: No, information presented is based on theories of the two systems.

Mr. Fife: Did the blended lot dye the same as the control lot?

Mr. Fiori: The blended fabric was neppier and slightly darker than the control fabric.

THIRD SESSION

Chairman: C. Norris Rabold

SOME RECENT ADVANCES IN WASH-WEAR RESEARCH

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The amount of cotton treated with wash-wear finishing agents has increased steadily. The term "wash-wear" is applied, however, in a somewhat indiscriminate manner so that in some cases so-called "wash-wear" garments are hardly minimum care. On the other hand, some garments which are fairly satisfactory, particularly men's white shirts, have come on the market and there has been observed an encouraging trend toward the production of high quality garments. These high quality materials are sometimes associated with a trademark and are often backed with a guarantee, a combination which seems to permit more leeway in use

of a higher cost finish. There is great promise of improved wash-wear products if consumer confidence can be maintained through use of better finishes and a money-back guarantee.

Many problems remain in wash-wear. Chief among these is the need to improve durability, particularly toward home bleaching and commercial laundering. "Seam pucker" has been stated to be a problem second only to durability. Poor appearance of cloth due to "pebbling," and shrinkage, perhaps due to overstretching, undercuring, or other poor technique, is bothersome. Odor problems are always with us, due mainly to no or insufficient afterwashing. A tremendous amount of work in industry and at SU is being done on these problems. Only a small portion of the work being done commercially is published, but the type of work can be judged from that described at the recent ACS symposium on crosslinking, the National Cotton Council's Chemical Finishing Conference, and changes in the types of finishing agents being used, such as increased production of melamine and the use of urons.

Work on Wash-Wear at SU

Work at SU has been reorganized recently, and most work on wash-wear is being done in the Wash-Wear Investigations of the Cotton Finishes Laboratory. Work which was started in other groups before the reorganization is being concluded in those groups and some work has been transferred to the Wash-Wear group.

Aziridinyl Compounds. "APO" (Tris-aziridinyl phosphine oxide) has been used to make wash-wear yard goods and has also been applied to garments in the laboratory. About 7% add-on gives good wash-wear ratings. Durability to all types of laundering, including strongly acid souring conditions, is excellent. However, the APO finish is not suitable for white goods because a slight yellowing occurs on bleaching with hypochlorite. Much work has been done in an effort to overcome this defect, but so far no way has been found. The yellow color can be removed by oxidative or reductive bleaching such as with sodium perborate or sodium borohydride, but it returns on further treatment with chlorine bleach.

Other aziridinyl compounds such as the one obtained from phosgene, carbonyl bis-aziridine (CBA), have been investigated. The CBA compound also gives good wash-wear ratings, with about 5% add-on, but it yellows with chlorine in the same manner as the APO finish.

Epoxy Compounds. A diepoxide such as 1,3-diglycidylglycerol may be reacted with cotton in a pad-dry-cure process using strongly acid catalysts such as magnesium perchlorate, aluminum sulfate, or zinc fluoborate to produce a wash-wear finish with excellent durability. Unfortunately, the high acidity causes degradation of the cloth. In an effort to lesson degradation, coreactant materials such as phthalic anhydride which could also serve as catalysts were used with the diepoxide. In some cases good wash-wear was obtained, but strength losses were disappointingly high and alkali caused hydrolysis of the crosslinks.

In another investigation it was found that addition of certain diepoxides to cellulose using zinc fluoborate catalyst can be controlled by variation of curing conditions and changes in the diepoxides: $Zn(BF_4)_2$: AGU mole ratios. With the proper selection of mole ratios for these diepoxides (1,3-diglycidylglycerol, the diglycidyl ether of 1,4-butanediol, and vinylcyclohexene diepoxide) it is possible to achieve good wet and dry crease resistance at relatively low add-ons without undue sacrifice of strength. For a given mole ratio of reactants, a lower curing temperature gives improved strength for a given improvement in crease recovery. Further add-on, probably due to in situ polymerization, reduces dry crease resistance and tearing strength, but has little effect on wet crease recovery or breaking strength.

The addition of butadiene diepoxide to cotton in the presence of zinc fluoborate catalyst could not be controlled by variation of curing conditions or molar ratios of reactants. Regardless of techniques used, only 1-2% of this diepoxide added to cotton. However, this small addition from methanolic solution was sufficient to impart excellent wet and dry crease resistance. Although an equal add-on could be obtained from water solutions, crease resistance was not obtained. This diepoxide was the only one of the four investigated which showed this peculiarity.

Structure of Fabric. The Cotton Mechanical Laboratory is working on a project to improve the structure of wash-wear cotton fabric, in cooperation with the Chemical Finishing Laboratory. Effects of twist multiplier, weave, and so forth are being investigated in an effort to improve strength of wash-wear cottons.

Fundamental Work on Wash-Wear Agents. Basic research occupies about 40-50% of the effort in the Wash-Wear Investigations, and the theoretical side as well as the practical is always considered. Work is being done on the effect of various substituent groups on stability toward acid hydrolysis and toward chlorine bleaching. However, some of this work will be considered in a later presentation on the effects of the nature of the crosslink.

Substituted Formamides. Work on these materials has shown that, contrary to other N-substituted carboxylic amides, N-substituted bis formamide gave relatively efficient crosslinking agents with formaldehyde. They are also more acid stable; they have the highest acid stability of all the methylol amide finishes. Unfortunately, however, they are sensitive to chlorine degradation.

The Urons. The effect of substituents on the stability of the uron ring was investigated. Some urons are cleaved and others are fairly stable. Pure bismethoxymethyluron has excellent resistance toward chlorine damage. Most commercial urons contain dimethylol urea as an impurity which makes them susceptible to chlorine. However, the good bath stability and low cost of the urons has made them popular for many commercial applications.

Acetals. Various unsymetrical bis formals have been prepared in an attempt to make a more reactive crosslinking agent of this class. However, severe strength loss occurs when high crease recovery angles are obtained. Presumably, the high acidity needed to catalyze the reaction with cellulose causes the excess degradation.

Formaldehyde Finishes. A new line project has been established in Wash-Wear Investigations to extend the work of Reeves, Chance, Perkins, Guthrie, and others. All phases of formaldehyde reaction with cellulose are under consideration, including the "Form W" which gives wet crease recovery with little increase in dry crease recovery; the "Form D" process by several methods which gives both wet and dry crease recovery; the "Form V" method which uses formaldehyde vapor; and the pad-dry-cure method. Dr. Guthrie will describe the vapor phase reaction later.

With the wet processes a number of factors have been studied. These include acid stability, strength losses, effect of premercerization, and the amount of formaldehyde needed for crosslinking under various finishing conditions.

For example, it has been found that the acid resistance of Form W and Form D crosslinks is very high, but not as high as those formed in the pad-dry-cure method, probably because the crosslinks are more accessible to water. However, by treatment of Form W cotton with a catalyst such as zinc nitrate and heat curing, the crosslinks are apparently cleaved and reformed with the cellulose deswelling in the process so that the cloth acquires dry crease resistance.

EFFECTS OF THE NATURE OF THE CROSSLINKING AGENT UPON COTTON FABRIC PROPERTIES

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Most researchers accept the idea that crosslinking is needed in the development of wash-wear cotton. Several factors affect the extent or amount of the wash-wear property that is imparted by crosslinking. For one thing, the extent of crosslinking is very important. The extent of wash-wear property develops rapidly as crosslinks are introduced. At first, relatively great increases in wrinkle recovery properties are imparted with relatively few crosslinks. Finally, a maximum is reached in wrinkle recovery where additional crosslinks appear to do little or no good.

The extent and type of wrinkle recovery is influenced to a considerable degree by the amount the fiber is swelled at the time it is crosslinked. For example, when the fibers are crosslinked in a collapsed state, wet and dry wrinkle recovery is usually obtained as with the N-methylol finishing agents when they are applied by the pad, dry, cure technique using a latent acid catalyst. The extent of molecular substitution for maximum recovery with N-methylol agents is about 0.05 which means one molecule of a crosslinker per twenty anhydroglucose units. Mostly wet wrinkle recovery results when the fiber is crosslinked while swelled. The amount of formaldehyde needed to impart a high degree of both wet and dry recovery can be decreased to a molecular

substitution of 0.015 by applying it as a vapor. This indicates that this agent is either a very efficient crosslinker or the crosslinks are in a highly desirable region of the cotton fiber.

There are two schools of thought about how wet WR is brought about in cotton. One school considers that crosslinking through covalent bonds is necessary. Just recently at the ACS meeting in St. Louis, Dr. Tessoro illustrated with some sulfone derivatives that wet-WR is not obtained unless the reagent is capable of crosslinking. Others have said that wet-WR can be increased by certain cotton finishes that cause the cotton to absorb more water. An important point of this talk is to present some evidence to show that both schools of thought are correct in a limited way and that there is still another factor affecting wet-WR. First of all, it should be emphasized that wrinkle recovery is conventionally measured by two tests--(1) determination of the recovery angle as with the Monsanto Wrinkle Tester and (2) determining the wash-wear rating according to the AATCC test procedure. There is some correlation between these tests but it is not perfect. From a practical point of view, the shadow-box rating is most meaningful. After all, the property desired in wash-wear goods is the ability to dry smooth and remain free of wrinkles while in use.

The type derivatives of cotton that can be used to illustrate that crosslinking is necessary are hydrophobic derivatives. Such mono-functional compounds do not increase wet wrinkle recovery when tested by measuring the recovery angle. Cotton derivatives that increase the amount of water of imbibition increase wet wrinkle recovery.

If the increased wrinkle recovery is due solely to imbibition, then one would expect much higher wet wrinkle recovery of those derivatives that imbibe the greatest amount of water. This is not the case. Wet wrinkle recovery of the fabrics in the free acid form such as carboxymethylated is significantly greater than the values for the corresponding fabrics in the sodium salt form which imbibe much greater amounts of water. It is believed that this observed difference is accounted for by hydrogen bonding. Generally, one thinks that hydrogen bonds are easily broken by water, especially those in the more accessible region of the cotton. This certainly must be true under many circumstances. At the same time, most researchers agree that water does not break hydrogen bonds and penetrate highly ordered regions of the cotton cellulose. Thus, hydrogen bonds are not always broken by water. In the sodium salt form the highly positive sodium ion decreases the electron density about the carbonyl oxygen. The electronegativity of the carbonyl oxygen greatly influences the strength of any hydrogen bonds formed through it.

Two hydrophobic cotton derivatives, acetylated and benzylated, were given wash-wear ratings after tumbling dry. The acetylated cotton contained about 21% acetyl, whereas there was a 9% weight gain due to the benzylation. In each case, one-half of the samples were autoclaved under slight tension at 20 pounds of steam for 30 minutes. The wash-wear ratings after tumble drying showed that autoclaving increased the wash-wear ratings. It seems reasonable that the secondary cell wall structures of the modified cotton fibers had an opportunity to become

better aligned during the autoclaving. As a result of better alignment, hydrogen bonding was increased. The hydrophobic nature of the derivatives helped to protect the hydrogen-bond crosslinks.

Discussion

Mr. Getchell: Was the effect on tensile or tear strength checked on the material which was supposedly hydrogen bonded?

Mr. Reeves: The tensile strength was fairly high. Little or no change because of this.

Mr. Fortess: The whole field of wet wrinkle recovery is new. Can't it be explained by mechanics? Furthermore hydrogen bonding should be greater in the dry state than in the wet state.

Mr. Reeves: Hydrogen bonding is not always broken up by water. For example: in crystallites it is protected. The swelling phenomenon does contribute, but is not the sole factor.

Mr. Fortess: With the sample having 96% imbibition you may have gone too far. You get thermoplastic flow and deformation. There must be an optimum imbibition.

Mr. Reeves: Maybe so. The purpose of this talk is to stimulate thought. My present thinking is that someday we may have wash-wear without crosslinking.

Dr. L. Smith: Is there a time limit on crease angle test?

Mr. Reeves: Yes. I will give you the complete test later.

USE OF DIVINYL SULFONE ADDUCTS IN WASH-WEAR FINISHES

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A large family of new finishes for cotton has been developed based on the unusual chemical properties of divinyl sulfone. This highly activated diolefin, which is now commercially available, can be used to attach active hydrogen compounds to cotton while simultaneously crosslinking the cellulose to impart wrinkle resistance. In view of the hundreds of inexpensive active hydrogen compounds available for preparing such crosslinked and substituted ethylsulfonylethyl esters of cellulose, a broad spectrum of fabric properties can now be obtained in conjunction with wash-wear qualities.

Classes of organic compounds which have been bonded to cotton include aromatic amines, secondary aliphatic amines, alcohols, aminoalcohols, amides, phenols, ketimines, heterocyclic amines, and amino acids. Inorganic compounds which also react include water, ammonia, sodium bisulfite, hydrogen sulfide, and buffered sodium azide. Although divinyl sulfone itself has a highly irritating odor, it forms odorless addition products with the active hydrogen compounds. Such adducts have in most cases proven to be soluble materials easily applied in conventional equipment. Their reaction with cellulose is rapidly effected by oven curing with alkali catalysts. Sufficient redissociation of the adducts occurs during curing to generate *in situ* the divinyl sulfone needed to give crosslinking and crease recovery.

The preparation of the adducts is ordinarily simple and rapid. Amine adducts are often formed at room temperature by mixing the reagents in aqueous solution. The adducts of divinyl sulfone with alcohols are formed at 25-100° C. in the presence of catalytic amounts of such bases as sodium hydroxide, sodium alkoxides, tetramethylguanidine, or benzyltrimethylammonium hydroxide. Traces of unreacted divinyl sulfone in the adducts may be removed by addition of water followed by extraction with benzene.

With water, divinyl sulfone reacts at 40-95° C. in the presence of alkaline catalysts to form both cyclic and linear adducts. Only the linear adducts appear to be reactive toward cellulose.

Adducts of divinyl sulfone with polyfunctional active hydrogen compounds show increased reactivity. They appear to undergo graft polymerization on cellulose, simultaneously with the occurrence of crosslinking and single substitution. Polyhydric alcohols ranging from ethylene glycol to starch have been attached to cotton. Amino alcohols behave similarly. Linear and cyclic polyamines ranging from piperazine or ethylenimine to polyethylenimine have been readily bonded to cellulose. A number of dyes containing amino or phenolic groups have been bonded to cotton. These dyes show unusual durability to concentrated mineral acids and alkalies at room temperature.

Interesting effects of mercerization have been noted on fabrics treated with divinyl sulfone adducts. Pre- or after-mercerization frequently enhanced wet crease recovery, and in the case of after-mercerization, surprisingly increased the tensile strength at the same time.

It is obvious that the use of divinyl sulfone derivatives forms a new and rapidly expanding research area in the field of crosslinked celluloses, with particular applications to wash-wear fabrics.

Discussion

Question: Do treatments affect the shade obtained on the fabric with a given dye?

Dr. Welch: No information was available on this subject.

Mr. Getchell: How do the treatments affect the moisture regain of cotton?

Dr. Welch: No data is available.

Mr. Getchell: Is there any known explanation for the types of crease recovery obtained?

Dr. Welch: The method is so new and includes so many different types of finishes that it seemed unwise to generalize.

Question: Have studies been made on the toxicity of the divinyl sulfone adducts?

Dr. Welch: Information is available in the literature showing that several of the adducts are relatively nontoxic, are completely free of lachrymatory and vesicant properties, and do not cause burns or irritation when in contact with the skin. In the present work, no odor or allergy problems have been encountered with any adduct prepared thus far.

IMPARTING CREASE RESISTANCE TO COTTON FABRICS WITH VAPOR FROM HCl-PARAFORMALDEHYDE

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A dust, made by exposing paraformaldehyde powder in a closed container to the vapor from concentrated hydrochloric acid, was found to be particularly effective and convenient for experimental treatments of cotton fabrics and other materials. Good wet and dry crease recovery was obtained by dusting fabrics and holding them between glass plates, but a more convenient and effective way was to expose the fabric in the same container as the dust, but without contact with it. Fabrics and completed garments, such as carefully ironed cotton shirts, were treated in a polyethylene barrel.

In dusting experiments between glass plates, using HCl-paraformaldehyde containing about 0.9 percent HCl, it was observed that if oven dried fabric was used in a manner to avoid much uptake of moisture from the air, rather small improvement in wet or dry crease resistance was obtained and that little formaldehyde reacted with the fabric. Air equilibrated fabrics, however, gave wet and dry crease recovery angles of 280 to 300° W + F at 0.5 percent formaldehyde and 270 to 290° at 0.35 percent formaldehyde when treated for one to two days. Breaking strength losses were 40 to 50 percent. Dyeings of the treated fabrics with Direct Blue 4 GL showed marked dye resist, but poor uniformity.

In the treatments made in the polyethylene barrel time of removal of the samples, usually 20 to 30 hours, was determined by inclusion of a small piece of similar fabric which was removed and tested by hand crumpling, wet and dry. Crease recovery angles of 280 to 300° W + F were obtained at 0.48 percent formaldehyde, with a breaking strength loss of about 50 percent. Angles of about 270° W + F were obtained at about 0.2 percent formaldehyde with a breaking strength loss of about 40 percent. Comparable losses were observed in tearing strength; and the losses in flex abrasion was very great, as is typical of most formaldehyde treatments.

If washing of the samples after exposure to the vapor was omitted, the formaldehyde content was lower than in the washed samples when analyses were made several months later, probably due to the reverse catalytic action of the hydrochloric acid before it diffused from the unwashed samples. There may have been a slight decrease in crease angles due to omission of washing, but strength retention was not significantly affected.

A plot of formaldehyde content against recovery angles for the vapor treatments showed that crease recovery angles of 250 to 270° W + F, wet or dry, were obtained at about 0.11 percent formaldehyde. This is about one-seventh of the formaldehyde content required for comparable crease recovery angles in the form D process, and may be calculated to indicate not over one crosslink per 160 anhydroglucose units. Good dye resist, with uniformity, was shown by the treated samples; and this resist was greater than with samples of the form D process.

Typical fabrics treated by the vapor process to a formaldehyde content of about 0.2 percent were laundered and tumbled dried 20 times. There was little change in the formaldehyde content due to laundering. Small decreases in the dry crease recovery of the treated samples due to laundering were observed, there was some tendency for the breaking strength to increase, and thread counts indicated stabilization toward shrinkage. The losses in tear strength and flex abrasion of the treated samples, in comparison with the control samples, became less evident on laundering. The original wash-wear ratings of four fell to three after 20 launderings. Numerous miscellaneous experiments were made.

Treatments of cotton yarn showed the expected reduction in strength and elongation at break. Treated sliver showed lack of uniformity in dye resist and other tests, but showed somewhat greater recovery from compression. The vapor treatment appeared to be effective on fortisan and fortisan cotton blends. Treatment of a cut pile cotton rug sample gave slightly more compression resistance of the pile, but the treated sample soiled more than the untreated control in a use test. The vapor treatment was effective in fixing the glaze on fabric that had been friction calendered. It was observed that the vapor from the HCl-paraformaldehyde would penetrate two layers of broadcloth to effectively react with the third. A number of carefully ironed cotton handkerchiefs were treated after careful ironing. They gave satisfactory service, remained smoother than the controls during use, and required little ironing after laundering.

During the course of the investigations, 20 shirts were treated individually in the barrel, along with miscellaneous fabric samples. Most of these shirts were of white, shrinkproofed broadcloth and had fused collars. They have been worn and laundered by various people. Up to the present time, only one has failed in service, due to bursting at the elbow(after six launderings with bleach) when the wearer was putting on a sweater. It had very good wash-wear properties and a formaldehyde content of 0.46 percent. Most of the other shirts show fair to good wash-wear properties, and all are much smoother than control shirts after laundering and tumble drying. The treated shirts have a tendency to retain more soil than control shirts; and when a side-by-side comparison is made, the control shirt appears whiter. Creases ironed into the shirts prior to treatment remain after 20 launderings. Seam pucker, although less than in the control shirts, is evident in the treated shirts. In general, the impression of most wearers is that the shirts are good at first with respect to wash-wear properties, but that they would require some ironing after about 10 launderings.

Discussion

Mr. Fortess: Were samples of the treated fabrics sent to Microscopy to determine if reaction was merely on the surface of the fiber?

Dr. Guthrie: No. However, since the conference, samples were submitted. Mr. Tripp found that reaction took place throughout the fiber.

THERMOPLASTIC COTTONS

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Thermoplastics, a subdivision of a much larger class of materials known as plastics, are characterized by a quality of softening or melting at some higher temperature and hardening again at lower temperatures. They are, therefore, capable of being shaped or molded into useful articles to supply human needs. Like all plastics they are composed of high polymer, linear, usually organic molecules. Thermoplastics differ from another large class of plastic materials, namely, thermosetting resins in their response to higher temperatures. Whereas, thermosetting materials do not soften again after having once been heated, and molded thermoplastic materials undergo softening and hardening repeatedly as the temperature is raised and lowered. Commercial examples of thermoplastic materials are vinyl resins, polystyrene, and various acrylate resins.

Since thermoplastic materials are normally amorphous or low crystalline substances, their behavior with temperature is most clearly revealed by plotting their stress-relaxation modulus on a log scale against temperature. This, also, permits comparison of their behavior with that of crystalline and of crosslinked amorphous polymeric materials. In this way thermoplastic materials are characterized by a transition temperature at which the softening or glassy state rapidly changes into a rubbery state. At still higher temperatures the rubbery state gives way to a plastic or flow state and usually, finally to a melting state.

Crystalline polymers, to the extent that they contain amorphous fractions, show a more or less limited glass - rubbery transition temperature, followed by a gradually decreasing modulus and eventually liquefaction at the melting or decomposition temperature. Crosslinked resins, represented for example by urea or melamine formaldehyde, show the same type of glass - rubbery transition temperature as thermoplastic materials, but the rubbery state of the material more usually extends to much higher temperatures and, eventually gives way to a decomposition range of temperature rather than to a melting temperature.

How do cotton and its products fit into the above picture? First, let us consider unmodified cotton cellulose. This is, of course, not thermoplastic. When the stress - relaxation modulus, on a log scale, is plotted against temperature, it behaves like a highly crystalline material. The curve begins in the glassy state and undergoes a small dip as the temperature rises to the boiling point of water. This is a moisture effect and disappears as soon as the moisture distills away above the boiling point. As the temperature rises still further, the modulus decreases slowly at a nearly constant rate until eventually decomposition occurs.

"Thermoplastic cottons," so called, are those which have been chemically modified, usually by esterification or etherification. Some years ago in our Division, cotton fabric was cyanoethylated to a degree represented by 10-11% nitrogen. It was observed that the resulting product was heat sensitive. It softened materially on heating. However, this behavior was not studied further at that time. More recently it has been found that highly acetylated (FA) cotton softens somewhat

on heating and that when fabric of this type is ironed, it can be fixed into permanently pleated or creased state.

The nature of the processes in "thermoplastic cottons" have been gradually becoming clear. First, cellulose itself is a highly crystalline material and in this respect behaves as a highly crosslinked high polymer. The crosslinking elements are the hydrogen bonds which tie so many of the neighboring chains together into crystalline domains. However, by chemical reaction, as by cyanoethylation or acetylation, to high degrees, the hydrogen bonds are disrupted. If reaction is carried sufficiently far, cotton cellulose behaves as a noncrystalline material. Its extensibility is improved and its brittleness reduced. Furthermore, a number of these materials become strongly heat sensitive.

The nature of the heat sensitivity has been more thoroughly studied during the last year or two. Our Laboratory has made a study of the thermal behavior of highly cyancethylated cottons. And both the Cotton Finishes (formerly Cotton Chemical) Laboratory and our own have studied highly acetylated cottons.

The thermal behavior of these highly modified materials starts out in the thermoplastic manner. As the temperature is raised they become softer, but not sticky nor fusible. However, it has been demonstrated that at sufficiently high temperature the material can be creased or molded and thereafter, as the temperature is raised and lowered, the transformation is not reversible. In this respect these materials behave much as thermosetting resins. The peculiar behavior is due to the fact that as these materials are heated a temperature is eventually reached at which the noncrystalline cellulose derivative begins to

crystallize. This is true of both cyanoethyl cellulose and FA cotton. These materials do not crystallize into the original crystal type of the native cellulose but into a new crystal type characteristic of the particular cellulose derivative present. Cyanoethyl cellulose has a strong X-ray diffraction peak at an angular position of about 10.3° 2θ. On the other hand highly acetylated cotton cellulose has strong X-ray diffraction peaks at about 7.6° and 16.0° 2θ and less intense diffraction peaks at other angular positions .

During the process of heating cyanoethylated cellulose begins to crystallize somewhat at temperatures in the neighborhood of 100° C, reaches its maximum in the neighborhood of 170°C and melts or decomposes at about 180°C. We have not explored to determine whether this material can be made to recrystallize on cooling from its melt.

FA cotton begins to crystallize at about 170° C and continues to crystallize progressively with further rise of temperature to about 250° C; finally, it melts and decomposes at temperatures above 320°C. The amount of crystallization which occurs is clearly dependent on the amount of chemical modification present.

The ability of FA cotton to form pleats and permanent creases on heating is partially due to crystallization which, having set up at a temperature above its initiation point thereafter fixes the material in whatever shape or mold confined it before crystallization. Having setup it becomes more rigid and resilient and is stable at all temperatures up to the melting point. The permanent creasing or pleating capacity would be expected to be dependent on the amount of crystallizable substances present.

If the temperature of the acetate is carried above the melting point, it is not possible thus far to obtain recrystallization on cooling except in the most limited degree.

As a result of studies made thus far, it would appear that many opportunities may exist for new, unusual and perhaps advantageous thermal behavior of chemically modified cottons.

FOURTH SESSION

Chairman: Lawrence L. Heffner

FLAME RESISTANT COTTON

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Interest in flame retardants for cotton developed at the Southern Utilization research and Development Division has prompted additional work in this field. The work has been based on the very reactive resin forming monomer tris(1-aziridinyl)Phosphine oxide referred to as "APO."

APO which has three active aziridinyl groups per molecule can (1) react with cellulose, (2) condense with itself to form a polymer, and (3) react with other active substituents to form copolymers.

As a flame retardant chemical, APO appears to be very versatile. In addition to reacting with tetrakis(hydroxymethyl)phosphonium chloride (THPC) to impart flame resistance to cotton, other agents have been found

which can be used to replace the THPC in the formulation. Examples are various amines, compounds containing active methylene groups, phenols, carboxylic acids, and various alcohols.

When APO is reacted with cellulose in the presence of compounds of the above mentioned types, the polymer chains formed have the following reoccurring connecting structures:

<u>Amines + APO</u>

$-P-N-CH_2CH_2-N-P-$; $-P-N-CH_2CH_2-N-R$, where $-N-R$ is an alkyl amine.

<u>Compounds Containing Active Methylene Groups and APO</u>

$-P-N-CH_2CH_2-\underset{R_3}{\overset{R_1}{C}}-R_2$ and $-P-N-CH_2CH_2-N-P$, where R' is a hydrogen atom, an alkyl or aryl group; R_2 is an electronegative group; and R_3 is an electronegative group or an alkyl or aryl group.

<u>Phenols + APO</u>

$-P-N-CH_2CH_2-OR$ and $-P-N-CH_2CH_2N-P-$, where R is an aryl group.

<u>Carboxylic Acids + APO</u>

$-P-N-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-R$ and $-P-N-CH_2CH_2-N-P-$, where R is an alkyl or aryl group.

<u>Alchols + APO</u>

$-P-N-CH_2CH_2-N-P-$ and $-P-N-CH_2CH_2-OR$, where OR is an alkoxy group.

Combustibility of cotton can be reduced by impregnating the fabric with an aqueous solution, or uniform suspension on dispersion, removing excess liquor by passing the textile through squeeze rolls, drying the

fabric at about 100° C., and curing at about 150° C. The finish is resistant to alkaline and acid laundering and also to drycleaning. The degree of flame resistance obtained is dependent on the weight add-on of the chemicals on the cotton.

APO can be used to impart flame retardancy to cotton by using an acid catalyst, $Zn(BF_4)_2$. The process is simple and can be carried out on standard textile resin finishing equipment. It consists of impregnating the fabric with an aqueous solution of the resin forming monomer and catalyst by immersion and removing the excess solution by passing the wetted fabric through squeeze rolls, followed by drying and curing. Heat (with the help of the catalyst) initiates the reaction with cellulose and also cures the water-soluble resin forming monomer, producing an insoluble highly crosslinked polymer inside the cotton fiber. Dimensional stability, wrinkle, rot, mildew, and glow resistance are imparted to the fabric, in addition to flame resistance.

Cotton fabric of 8-9 oz./yd. weight requires approximately 11-14% resin add-on to pass the standard vertical flame test.

APO has been found to be reactive with the chlorotriazine dyes, and when applied to cotton imparts brilliant colors which are durable to laundering. Additional plus features are rot, mildew, crease, flame, and glow resistance.

Discussion

Question: Where is APO available?

Mr. Drake: A correspondence aid publication is available which lists companies producing APO.

Question: Has any work been done on determining the amount of char/tar ratio upon burning APO-THPC treated materials? This question asked because the questioner has found that the gases given off upon charring, reduce the insulation properties of the treated material from a rating of 20 to a rating of 6.

Mr. Drake: No work has been done at this Laboratory, but some work had been done along this line in a contract project.

Question: Do wash-wear properties of APO treated materials remain unchanged after repeated laundering?

Mr. Drake: Wash-wear ratings remain essentially the same. A drop from 5 rating to 4 rating was noted after 15 launderings.

WEATHER- AND ROT-RESISTANT COTTON PRODUCTS

Preliminary Studies on Mixed Pigment Impregnations

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A number of papers on the effect of individual pigments on the outdoor durability of coated and impregnated heavy and light weight cotton fabrics have described earlier weathering studies conducted at the Southern Utilization Research and Development Division. Subsequent analysis of these data revealed two significant trends--(1) a high degree of protection to one weight of fabric (duck) did not necessarily mean high protection to a different weight (printcloth), (2) biological resistance ratings correlated well with breaking strength retentions on duck. It became apparent that the protection afforded to printcloth

was due primarily to protection from sunlight degradation, and protection to duck was protection from biologic deterioration. Pigments could now be classified as "Sunlight" (protection) and "Mildew" (protection).

Utilizing the classes developed above, mixtures of pigments in appropriate shades (pearl gray, field, and olive drab) and designed to give both mildew and sunlight resistance were formulated and applied to eight-ounce army duck. These treated fabrics were exposed for a two-year period. Examination of the exposed fabrics showed complete inhibition of any visible mildew or algae growth. Strength retentions of up to 60%, as compared with 6 to 7% for untreated duck, were observed for the exposure period. Treatment levels were approximately 2% pigment add-on at pigment cost levels from 1.2 to 1.6 cents per yard of eight-ounce army duck. Typical pigment combinations were as follows:

Olive Drab

Chrome yellow (Sunlight)
Cadmium maroon (Mildew)
Raw umber (Sunlight)
Lampblack (tinting)

Pearl Gray

Rutile titanium (Sunlight)
White lead (Mildew)
Chrome yellow (Sunlight)
Cadmium maroon (Mildew)
Phthalocyanine blue (tinting)

Comparison of published data on the ultraviolet transmission spectra of individual pigments with the strength retentions of fabrics impregnated with similar pigments shows a more than chance relationship between ultraviolet opacity of pigment and high exposure strength.

retentions. A similar pattern is observed for ultraviolet transparent pigments and low exposure strength. Examples of the above relationships are as follows: white lead (averaging over 60% transmission in the sunlight ultraviolet region) on fabric gave about 30% strength retention for 12 months exposure on light fabric. Titanium dioxide white (average less than 25% transmission) gives over 50% on similar fabric.

Proposed mechanism for measuring the transmission reflection and absorption of treated fabrics in the sunlight ultraviolet region will be presented. Correlation of these data with the results of outdoor exposure testing on similar fabrics may lead to some insight into mechanisms of fabric protection and degradation and possibly afford a means of prediction of the weathering characteristics of treated fabrics.

Discussion

Question: What was the vehicle used in your finishes?

Mr. Brysson: Alkyd emulsions were used.

Question: How do your finished fabrics compare with Heffner's fabrics?

Mr. Brysson: We had less add-on which gave us two properties. Mr. Heffner's fabrics had more add-on, and he got four properties.

Question: Why haven't cuprammonium fluidity tests been used to support some of your facts?

Mr. Brysson: For these evaluations, too many tests would have to be carried out, approximately 10,000 tests.

ESTIMATED COSTS AND IN-SERVICE EVALUATIONS OF SOME NEW CHEMICALLY MODIFIED COTTON FABRICS

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Considerable progress has been made in recent months at the Southern Regional Research Laboratory in estimating costs of new chemical finishes for cotton and in evaluating the performance of chemically modified cotton fabric products and under actual service conditions. Information of this kind is useful because it supplies basic cost data on process and product; it points up necessary compromises in process and product to engineer the upscaling of laboratory developments; it permits an accurate comparison of performance in specific end use applications; and it encourages cooperation with industry, which, in turn, uncovers unexpected problems in the process and contributes to their solution at an early stage of the research.

In earlier papers (3, 13) new low-cost processes were discussed for converting cotton into textile products having improved flame-, heat-, mildew-, rot-, soil-, weather-, and wrinkle-resistance, water repellency, increased breaking strength and elongation, dyeability, solubility, reactivity, ion-exchange, and other improved properties, and the market potential for PA cotton was evaluated on the basis of in-service performance. Additional costs and/or in-service fabric evaluations are reported in this paper in the areas of improved wrinkle-, flame-, heat- and scorch-resistance, and water repellency. Specifically costs reported in this paper are those estimated for hypothetical plants for

finishing cotton fabric with formic acid colloid of methylolmelamine to impart wrinkle- and muss-resistance (4, 10), with APO[1]-THPC[2] resin for flame resistance (12, 14, 20, 21), with silicone alloy for water repellency, and with triazone dissolved in silicone alloy for crease resistance in addition to water repellency imparted by the alloy alone (8, 18). These finishings consist essentially of padding cotton fabric through chemicals, drying and curing at elevated temperatures, washing the cotton free of unreacted chemicals and byproducts, and final drying of the product. They are considered promising because of the magnitude of the markets for the quality improvements they impart, their ready application in the usual equipment for resin finishing, and their potentially low costs.

In-service fabric evaluations have been made recently and/or are in progress on acid-formaldehyde treated cotton fabric, cotton fabrics finished with ethyl triazone, a mixture of ethyl triazone and polyglycol acetal, triazine, and APO, all for imparting wrinkle-resistance; on APO-THPC resin treated fabrics for flame resistance; and on partially acetylated cotton for heat- and scorch-resistance.

WRINKLE-RESISTANT COTTONS

Wrinkle resistance is important in products for which more than 2.6 billion pounds of cotton and other materials are consumed annually (19). Approximately 90 percent of the annual consumption of broad woven fabric is in uses in which consumers want easy care qualities, and cotton accounts for 75 percent of the consumption of all woven

fabrics consumed in these applications. In 1959, more than two billion square yards of woven cotton fabrics were resin-finished for the easy care market.

Formic Acid Colloid of Methylolmelamine Resin Finish

A finish developed at the Southern Laboratory for imparting durable wrinkle- and muss-resistance to cotton is the formic acid colloid of methylolmelamine resin finish, illustrated in Figure 1.

(Insert Figure 1)

In the hypothetical plant of our cost study, desized, scoured, and bleached 80 x 80 cotton printcloth, 50 inches wide, 3.12 linear yards per pound, is padded through an aqueous solution containing 10.3 percent methylolmelamine and 11.9 percent formic acid (a molar ratio of 1 to 5) at a processing rate of 120 yards per minute; squeezed to a wet pickup of 80 percent; dried in a forced-air roller type drying oven for four minutes at a temperature of 80° C.; cured in the same type oven for four minutes at 140°C.; washed in hot and cold water in a continuous counterflow open-width washing range; and dried on a tenter frame. The product contains 7 percent resin add-on and possesses good wrinkle- and muss-resistance, maintaining good crease angles at least through twenty home launderings; yellows only slightly when exposed to hypochlorite bleach in comparison with considerable yellowing of conventional methylolmelamine finished cotton; has no more than the usual 30 percent breaking strength loss effected by

CONTINUOUS ACID COLLOID METHYLOLMELAMINE
RESIN FINISH FOR COTTON FABRIC

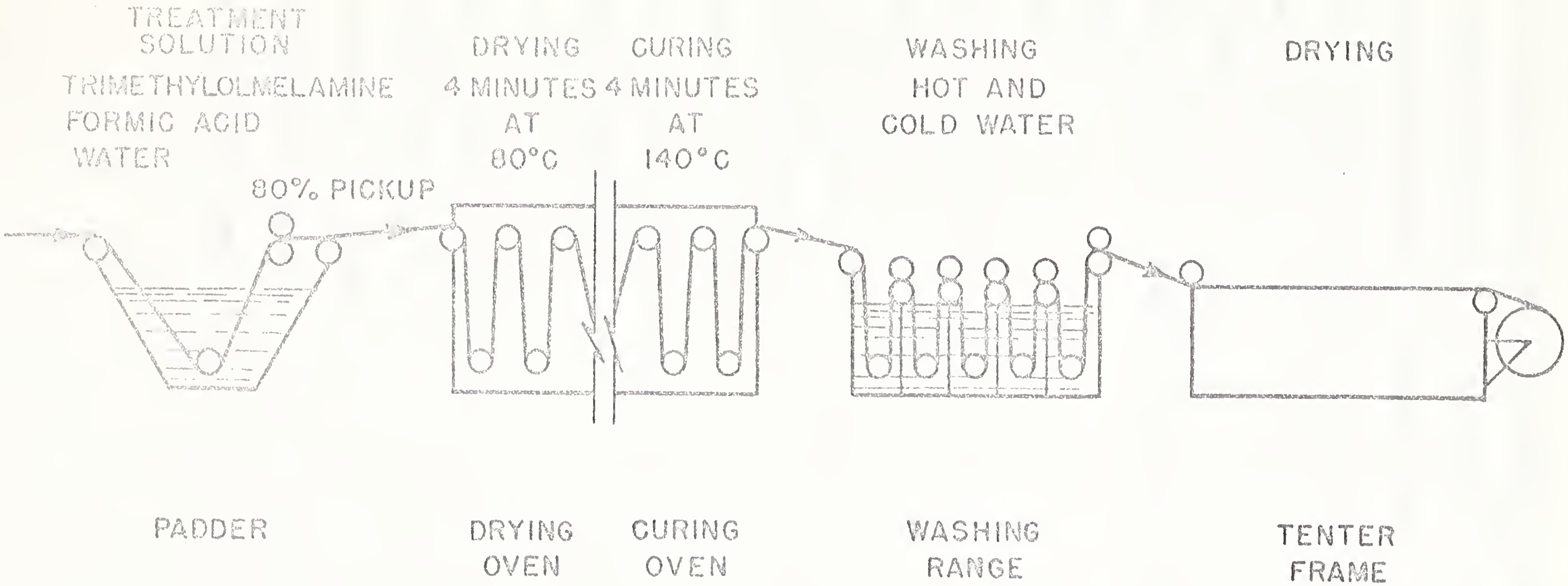


FIGURE 1

most resin finishes; before laundering, has tear strength losses of about 45 percent, which is in the same range as fabric treated in the conventional manner; and has good resistance to chlorine scorch damage even after repeated laundering. Estimated total processing costs range from 3.7 cents per square yard when operating 250 days annually, 8 hours per day, to 2.7 cents per square yard when operating 350 days annually, 24 hours per day. These costs are exclusive of the cost of cotton fabric and are for custom processing without profit.

Formaldehyde Finish

An in-service test program was set up at the Southern Laboratory to subjectively and objectively evaluate the wet wrinkle-resistance of cotton fabric treated with formaldehyde in the presence of hydrochloric acid. Eleven fabrics of varying processing history and construction were fabricated into sport shirts, blouses, pillowcases, boys' trousers, men's work shirts, and handkerchiefs. To supplement the wash-wear evaluation other variables were studied, such as scouring versus scouring and bleaching, mercerization versus nonmercerization, fabric construction, catalyst, and seamstress with regard to styling and seam pucker. In general, objective analyses indicated that wet and dry crease angle, tear strength, and break test remained almost constant. In contrast, subjective tests downgraded many of the garments due to extraneous appearance factors such as pebbling and seam puckering even though the crease angle recoveries were still good.

These results emphasize the necessity of supplementing objective test methods with subjective impressions, and point to the need for additional research before the formaldehyde treatment is ready for commercialization.

Other Wrinkle-Resistant Finishes

It has long been believed that because of their construction, currently popular fabrics are not necessarily the ones having best wash-wear properties. However, it would be extremely difficult to rectify this anomaly because most textile mills produce the largest quantities of apparel textiles to meet current or accepted fashion, and not because they are particularly suited for the proposed end use. One large market for apparel textiles not so inhibited is that for military uniforms. This market is almost ideal from a research standpoint. Its criterion is good in-service performance, regardless of fabric construction. Furthermore, adaptation of certain military garments for wash-wear properties would contribute to smart military appearance, and would benefit both the government and the individual in original cost and maintenance.

Accordingly, a comparison of several army type fabrics treated with commercial finishes and finishes developed at the Southern Laboratory was undertaken. The research consisted of two phases: (1) a determination of optimum add-on for each specific finish, and the effect of storage after treatment of fabric without curing,

followed by fabrication into garments and subsequent curing; and (2) a study of the durability of the finishes to various types of launderings. These evaluations were made on khaki twill, sateen, poplin, and steep twill during the first phase, and on khaki twill and poplin in the second phase. Four resin formulations, ethyl triazone, a mixture of ethyl triazone and polyglycol acetal, triazine, and APO were evaluated at three levels each in the first phase, and likewise in the second phase with the ethyl triazone-polyglycol acetal mixture omitted.

Some interesting data resulted. On crease resistance the ethyl triazone initially had the best overall properties with each of the fabrics tested and appeared to confer wash-wear properties independently of construction. For each of the resins except APO, which was not tested because of its self-polymerizing characteristics, storage for six weeks between resin application and curing enhanced the properties over those obtained by immediate curing. The APO finish exhibited the best durability to laundering based upon the resin concentration of resin needed for optimum wash-wear properties. In contrast the ethyl triazone was the least durable. The strength properties of the resin fabrics increased with increasing numbers of washings, and after 30 cycles of commercial and army mobile specification launderings were essentially equal to the control. On the basis of construction the khaki twill had better tear strength and flex resistance after resin treatment than before, and it resisted wrinkling better than did the poplin as measured by the subjective shadow box test.

It was concluded from the above evaluations that a khaki twill less dense than the presently specified construction, by virtue of longer floats, larger yarn size and fewer ends per inch would perform even better in-service, and a less lustrous finish would tend to make crease irregularities less obvious. Future work should include newer treatments such as the formaldehyde treatment, and limit itself to 8 oz. or heavier fabrics since it is apparent that the lighter weight fabrics can be satisfactorily treated with presently available commercial finishes. Service evaluations should be limited to stresses and hazards normally anticipated under actual use conditions so that the data will be informative and useful in predicting the behavior of the product being tested.

FLAME-RESISTANT COTTON

It is estimated that resistance to fire is an important quality improvement in consumer products utilizing almost two billion pounds of cotton and other materials annually (19). Important potential uses for fabrics treated with APO-THPC resin are flight, antigravity, fuel handler, combat, fatigue, industrial and commercial uniforms, aprons, nightwear, robes, tents, awnings, tarpaulins, draperies, curtains, upholstery, rugs, blankets, sheets, and mattress tickings. Fabrics have already been treated for application with APO-THPC resin in a number of these uses.

APO-THPC Resin Finish

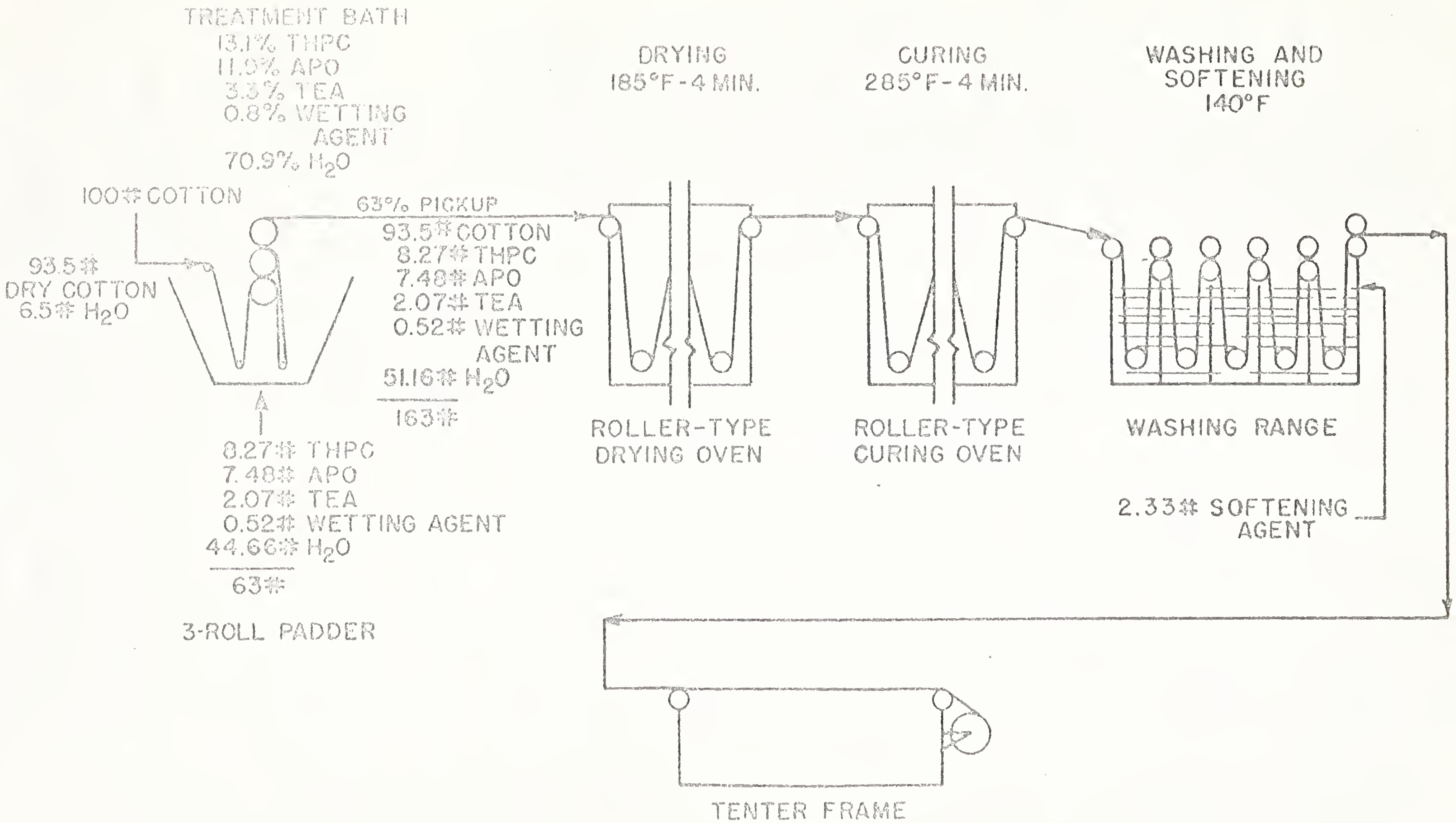
Cotton fabrics treated with APO-THPC come closer to meeting the requirements of ideal flame-retardant fabrics than those treated with previously known flame retardants. APO-THPC is one of the Southern Utilization Research and Development Division's flame retardants which have these outstanding features: durable to repeated launderings and drycleaning; glow-resistant as well as flame-resistant; when exposed to flames or intense heat, form tough, pliable, and protective chars; inert physiologically to persons handling or exposed to the fabrics; only slightly heavier than untreated fabrics; and susceptible to further wet and dry finishing treatments. In addition, the treated fabrics exhibit little or no change in hand, texture, appearance, or loss in strength and are shrink-, rot-, and mildew-resistant, and impart some crease resistance.

The process evaluated in the hypothetical plant of our cost study is illustrated in Figure 2. Eight-ounce cotton twill, 60 inches wide,

(Insert Figure 2)

0.81 pounds per yard conditioned weight is padded at a processing rate of 120 yards per minute through an aqueous solution of APO, THPC, triethanolamine and wetting agent; dried in a forced-air, roller-type drying oven for 4 minutes at a temperature of 185° F.; cured in the same type oven for 4 minutes at 285° F.; washed and softened in a continuous counterflow open-width washing range; and dried by any conventional method to a resin add-on of 10 percent. Reaction efficiency for the

CONTINUOUS APO-THPC RESIN TREATMENT OF COTTON FABRIC
10% RESIN ADD-ON



LEGEND:
THPC TETRAKIS (HYDROXYMETHYL) PHOSPHONIUM CHLORIDE
APO TRIS (1-AZIRIDINYL) PHOSPHINE OXIDE
TEA TRIETHANOLAMINE

Figure 2

illustrated treatment is between 60 and 65 percent based on APO and THPC added to the system. Using projected prices for THPC of 70 cents per pound and for APO of $2.25 per pound, total processing cost has been estimated to range from 15.3 cents per square yard when operating 250 days annually, 8 hours per day, to 14.3 cents per square yard when operating 350 days annually, 24 hours per day. Using long-range projected prices for APO and THPC of 30 cents per pound, it is estimated that the processing cost would be as low as 4.2 cents per square yard at the higher production mentioned.

Preliminary results of recent APO-THPC cotton fabric evaluations indicate that the finish is suitable for use on cotton fabrics over a very wide range of weights and constructions from lawn and batiste to heavy industrial belting, and that, in general, the amount of resin add-on required to achieve flame retardancy is approximately inversely proportional to fabric weight, with possibly few exceptions in which fabric construction may be the controlling factor, or in the case of blends of cotton with hydrophobic materials not reacted with the resin.

WATER-REPELLENT COTTON

Water repellency is an important quality in end uses for which almost one billion pounds of cotton and other materials are consumed annually (19).

Silicone Alloy Treatment

Investment and operating costs have been estimated for imparting durable water repellency to cotton fabric using a new silicone alloy treatment developed at the Southern Laboratory. Advantages of the

treatment, illustrated in Figure 3, are the low curing time and temperature

(Insert Figure 3)

required, no discoloration of the fabric, short processing time, and the fact that creaseproofing resins such as the triazones may be incorporated into the formulation. Although the alloy may be applied from organic solvents or aqueous emulsions, only the aqueous emulsion was considered in our cost study because of its ease of application, lower cost, and commercial adaptability. This treatment should enable cotton to further its expansion in the rainwear market and enter into the industrial market in uses in which water repellency and crease resistance are desirable.

In the hypothetical plant of our cost study, tetravinyl silane and methyl hydrogen siloxane are polymerized simultaneously for 90 minutes at 176° F. in the polymer tank using benzoyl peroxide as catalyst and methyl isobutyl ketone as solvent. The polymer is then transferred to a mixing tank where it is made into an aqueous emulsion using ethoxylated oleamide as the emulsifier. Zirconyl acetate, an organo-zirconium salt is added to the aqueous emulsion, and hydrolyzes on heating to form basic zirconyl acetate, which is deposited on the fabric and catalyzes the curing of the alloy. Then creaseproofing resins and their catalysts may also be added to the emulsion. The solution is then pumped to the padder, through which 5.5-oz. per square yard, 42-inch wide poplin is processed at a rate of 120 yards per minute, maintaining 90 percent wet pickup from the padder. The fabric is then dried for 20 seconds at 290° F., cured for 3 minutes at 325° F., and if creaseproofing resins have been added, washed with 140° F. water for one minute after curing, and dried on dry cans at 240°F.

CONTINUOUS PROCESSING SILICONE ALLOY-TRIAZONE FABRIC
120 YARDS PER MINUTE

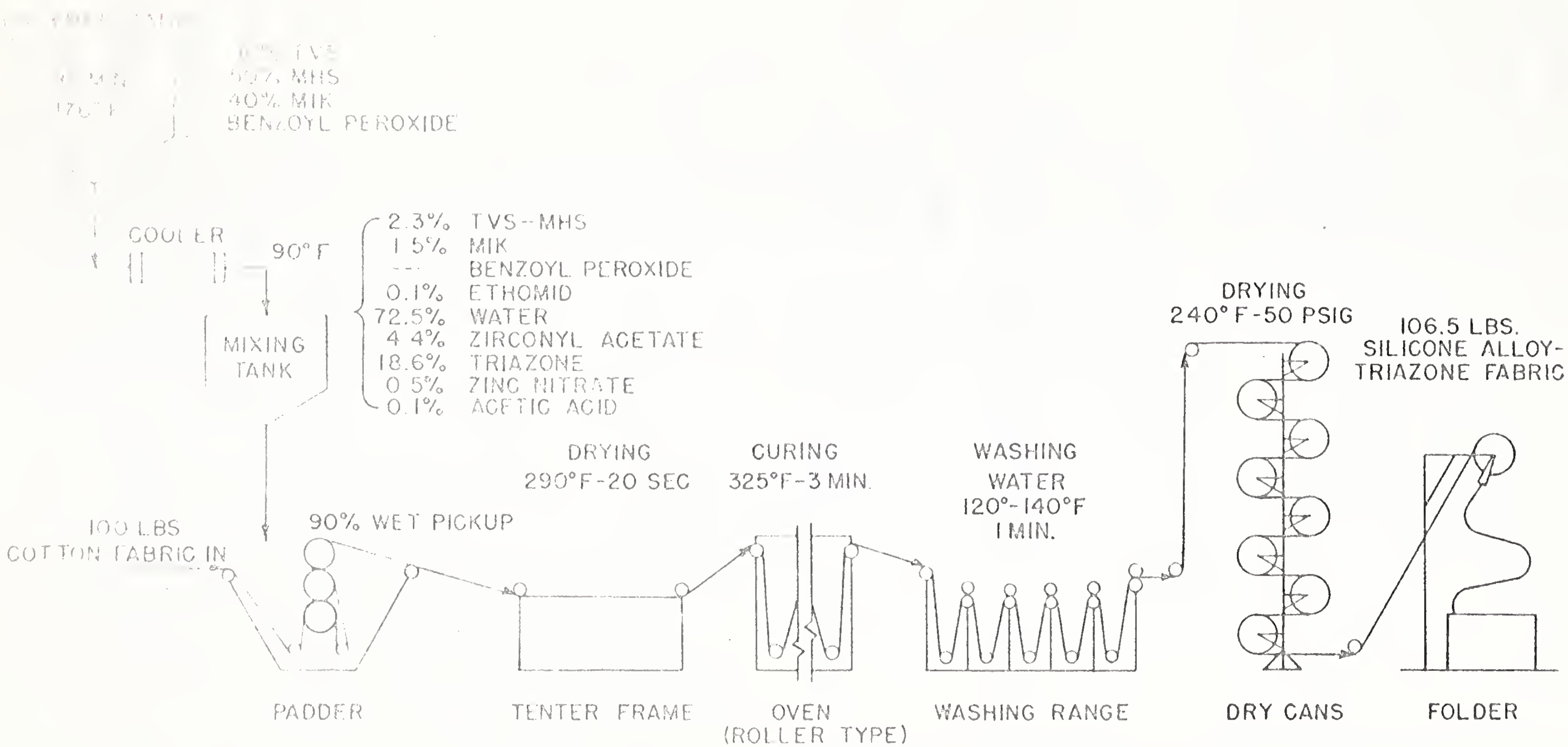


FIGURE. 3

Product add-on is 2.5 percent by weight if creaseproofing resin is not used, or 6.5 percent by weight if it is used. Estimated processing costs for the silicone alloy treatment range from 3.8 cents per square yard when operating 250 days annually, 8 hours per day, to 3.3 cents per square yard when operating 350 days annually, 24 hours per day. Those for the silicone alloy-triazone treatment range from 5.7 cents per square yard to 4.9 cents per square yard over the same operation range mentioned.

HEAT AND SCORCH RESISTANT COTTON

Resistance to heat is important in end uses in which almost 300 million pounds of cotton and other materials are consumed annually (19).

Partially Acetylated Cotton

Processes and costs for the partial acetylation of cotton raw stock, yarns, and fabric have been reported earlier (1, 2, 5, 6, 9, 11, 15, 16, 17), and fabric evaluations are progressing.

Cooperative research with several textile mills resulted in the production of various types and quantities of heat- and scorch-resistant cotton woven fabrics, knitted terry cloth and knitted padding from over 2,000 pounds of PA cotton. Some modifications in commercial textile mill practices were necessary to obtain satisfactory production of these PA laundry textiles. A statistically designed comprehensive service evaluation was carried out with the cooperation of commercial laundries on the products that appeared to have considerable indicated market potential. These service tests made it evident that heat- and scorch-resistant laundry textiles whose cost performance was favorable with that of competing materials could be produced. An important and unexpected

benefit observed was a minimum amount of the objectionable odor and dust that normally results from the progressive charring of untreated cotton in laundry service. Specifically--for hot head presses--sateen and basket weave fabrics, acetylated to approximately a DS of 1, outperformed plain weave fabrics acetylated to the same DS, as well as all other cotton fabrics tested of lower DS. These two fabrics had service lives about equal to resin-treated nylon, and 4 to 5 times as great as untreated cotton.

In general, no advantage was found in the acetylation of the yarn prior to weaving. For flat work ironers acetylation of the yarn was necessary because of the width of the rolls. Basket weave and sateen at DS of 1 were superior in this application to plain weave at DS of 1, and all fabrics of lower DS. Results indicate a service life for PA cotton 4 times greater than that of untreated cotton, and 45% that of dacron. Terry knit padding fabricated from acetylated yarn at DS of 1, proved to be an excellent padding material with service life in excess of 1,000 hours. Some washing was required to remove starch accumulation. Knitted sliver padding, consisting of a blend of 70% PA cotton and 30% untreated cotton performed equally well on both hot head presses and flat work ironers, displaying excellent heat resistance and satisfactory resiliency. Padding weighing 2.2 lbs./sq. yd., for hot head presses was in service in excess of 1,000 hours, and 4.5 lbs./sq. yd. padding lasted 48 to 50 weeks on flat work ironers.

Acetylated cotton fabrics of various constructions, as well as acetylated yarns, and other acetylated products, are being industrially

evaluated and appraised for such end uses as belting, plastic laminates, filter cloths, shoe fabrics, stretchable yarns, covering fabrics for high temperature molding operations, floor felts, and irrigation ditch liners. The Quartermaster Research and Engineering Division is evaluating PA cotton for resistance to radiation damage. The industrial potential of cyanoethylated cotton for some of these end uses is being cooperatively investigated with commercial organizations.

SUMMARY

Results of recent cost studies, tabulated below, indicate that

(Insert Table I)

wrinkle-resistance, flame-resistance, water repellency, and a combination of water repellency and wrinkle-resistance could be imparted to cotton fabric for a few cents per square yard using finishes developed at the Southern Regional Research Laboratory. These costs are based on a processing rate of 120 yards per minute and on projected chemical prices in the case of the APO-THPC resin finish; and they would be applicable to intermittent finishing at 120 yards per minute provided total annual production of all finished goods in a finishing plant falls in the range of that specified, namely 14.4 million linear yards (120 yards per minute, 8 hours per day, 250 days annually) up to 60.5 million linear yards (120 yards per minute, 24 hours per day, 350 days annually). Since these costs are for new installations,

Table 1. Chemical Modification of Cotton: Costs for Continuous Processing 1/

Processing Rate - 120 yards per minute

	Annual Production Million Linear Yards	
	14.4	60.5
Process	Cost, ¢/sq. yd.	Cost, ¢/sq. yd.
Acid Colloid	3.7	2.7
APO-THPC	15.3 2/ 5.2 3/	14.3 2/ 4.2 3/
Silicone Alloy	3.8	3.3
Silicone Alloy - Triazone	5.7	4.9

1/ Excluding cost of cotton fabric used. For custom processing without profit.

2/ Based on projected THPC price of 70 cents per pound and projected APO price of $2.25 per pound.

3/ Based on projected THPC and APO price of 30 cents per pound.

if equipment in a finishing plant is fully depreciated, processing costs would be less by as much as 0.5 cent per square yard at the low production level and 0.1 cent per square yard at the high production level, depending upon the finish used.

Results of a number of in-service evaluations of chemically modified cotton fabrics are reported. Other evaluations are underway in a variety of applications.

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INTERFACIAL POLYAMIDE TREATMENT OF WOOL FABRICS TO PROVIDE SHRINK RESISTANCE

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Summary

The IFP polyamide treatment is used primarily to control felting shrinkage in wool fabrics, but also reduces mussiness, reduces the amount of ironing required, and otherwise contributes toward easy-care properties of the fabric. More than 100 fabrics submitted by manufacturers for trial application of the polyamide treatment have responded well to the treatment and have been given a high degree of protection against felting shrinkage. Woolen and worsted fabrics and knit goods, in a variety of fabric weights and constructions, have been treated successfully.

The IFP polyamide treatment is applied by passing the fabric through two dip-pad operations in succession, followed by washing of the fabric to remove unreacted chemicals and to soften the fabric. The first dipping solution contains an aqueous solution of hexamethylene diamine, the second a solution of sebacoyl chloride in Stoddard solvent. The polymer forms rapidly in the goods at room temperature by a process known as interfacial polymerization and subsequent heat-curing is not needed. The polyamide polymer is chemically related to nylon, in this case nylon 610. Even less than 0.5% by weight of polymer will stabilize many woolen fabrics against felting shrinkage. Dense fabrics, particularly hard worsteds, may require as much as 2% by weight of polymer for control

of felting shrinkage. Preliminary experimentation with each different fabric is needed to establish the amount of resin or polymer required to give the desired control of shrinkage during laundering.

The treatment can be applied to dyed goods provided the dyes are fast under alkaline laundering conditions. The treatment tends to lighten the dye slightly with the darker shakes. Tests with acid premetallized dyes and acid milling dyes indicate that dyeing after polyamide treatment is feasible. In the tests on polyamide-treated fabrics, the dyes tended to exhaust slightly faster than on untreated fabrics; levelness of dyeing was excellent.

Limited tests indicate that blanket materials can be satisfactorily napped after polyamide treatment without excessive loss of shrinkage protection. To avoid matting of raised fibers, the IFP polyamide treatment should be applied to fabrics prior to napping or raising of a pile.

Depending upon the particular wool fabric being treated, the first padding solution contains from 0.5% to 2% by weight of hexamethylene diamine, sodium carbonate in twice the concentration of hexamethylene diamine used, and 0.1% by weight of a suitable nonionic surfactant. All concentrations are based upon solution weight unless otherwise specified. Hexamethylene diamine may be supplied as an aqueous concentrate rather than as a solid; the amount of concentrate to be used must be based on the actual amount of hexamethylene diamine in the concentrate.

The second padding solution contains 2% by weight of sebacoyl chloride in Stoddard solvent. This solution is used at the same concentration regardless of the concentration of hexamethylene diamine used in the first padding operation.

The fabric is first padded through the hexamethylene diamine solution at a load and speed that will give a wet pickup not exceeding 50% by weight on woolen goods, and preferably not more than 40% by weight for worsted goods. A fabric processing rate of 2 to 4 yards per minute in a hard-roll padder providing a load of 400 pounds per linear inch of roll width will give desired results on a wide variety of fabrics.

The amount of polyamide deposited in the fabric is controlled by the concentration of hexamethylene diamine in the first padding solution. The wet pickup of the fabric specified for the first padding operation must be maintained regardless of the concentration of hexamethylene diamine used in the first padding operation. As a general guide, a percentage by weight of hexamethylene diamine in the first padding solution will result in deposition of about the same percentage by weight of polymer in the fabric, that is, a concentration of 1% by weight of hexamethylene diamine in the first padding solution will result in a deposition of about 1% by weight of polymer in the fabric.

The fabric is then padded through the sebacoyl chloride solution with a load of 70% to 75% of that used for the first padding solution. No time delay is required between the two padding steps. If a single pad is being used experimentally for the treatment, with changing of

solutions between paddings, the amount of fabric being used should be limited. The hexamethylene solution is alkaline and the possibility of damage to the wool exists if the fabric is held in the wet alkaline condition for too long a period. However, time delays of 30 minutes between padding steps have not shown a loss in strength in the treated fabrics. When using a single pad experimentally for both padding steps, the immersion pan and pan rolls should be thoroughly washed down and dried before use in second padding operation.

The treated fabric is then dolly-washed to remove unreacted chemicals and to provide mechanical working during the washing step to soften the fabric. With the washing equipment used in these investigations (dolly-type washer), passage of the fabric through the rolls from 20 to 30 times was adequate to remove unreacted chemical and to soften the fabric.

The solution used for dolly washing and softening the fabric after polyamide treatment comprises 0.05% to 0.1% by weight of a suitable nonionic surfactant and 0.5% to 1% of formic acid based on the weight of the fabric. The small amount of formic or other suitable acid is provided to neutralize residual sodium carbonate and bring the pH of the fabric close to neutral.

Higher processing rates are being studied intensively. Effects of higher reagent temperatures, times of immersion in the chemical solutions, and skying between the dip tank and the nip of the padders, especially during the second padding step, are being investigated and process information thereon should be available within a few months.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOUTHERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

Conference on

RECENT ADVANCES IN COTTON UTILIZATION RESEARCH

GENERAL CHAIRMAN

M. Earl Heard
West Point Manufacturing Company
West Point, Georgia

May 1-2, 1961
Charcoal Room
Jung Hotel
New Orleans, Louisiana

Program Committee

R. M. Persell
R. J. Cheatham
W. A. Reeves
E. L. Patton

P R O G R A M

May 1, 1961 - 9:15 a.m. Charcoal Room - Jung Hotel		Louis L. Jones, Jr., Chairman Canton Cotton Mills, Canton, Georgia
	Welcome to the Conference	C. H. Fisher, Director, Southern Utilization Research and Development Division
	FIBER PROPERTIES AND MECHANICAL PROCESSING	
9:30 a.m.	Improvement in Cotton Quality Through Research	A. M. DuPre' Jr., Asst. to Adm., ARS
10:00 a.m.	Improved Mechanical Processing	R. J. Cheatham, Chief, CM, SU

May 1, 1961		Louis L. Jones, Jr., Chairman
10:30 a.m.	Intermission	
11:00 a.m.	Recent Advances in Textile Processing Machinery	R. A. Rusca, CM, SU
11:30 a.m.	Microscopical Observation of Fiber Damage in Cotton	M. L. Rollins and V. W. Tripp, CPP, SU
12:00 Noon	Luncheon Break	
		George S. Buck, Jr., Chairman, NCCA
1:30 p.m.	Drying and Cleaning Effects on Fiber Properties	J. N. Grant, E. Honold and F. R. Andrews, CPP, SU
2:00 p.m.	Origin of Short Fibers in American Cotton	J. N. Grant and R. H. Tsoi, CPP, SU; H. D. Barker, CR
2:30 p.m.	Intermission	
3:00 p.m.	Effect of Short Fibers in Cotton on Yarn and Fabric Properties and Spinning Performance	J. D. Tallant, L. A. Fiori and R. J. Cheatham, CM, SU
3:30 p.m.	Blending - A Means of Maintaining Quality in Cotton Products	L. A. Fiori and G. L. Louis, CM, SU

May 2, 1961 - 9:00 a.m.

C. Norris Rabold, Chairman
Erwin Mills
Cooleemee, North Carolina

CHEMICAL MODIFICATION AND FINISHING

9:00 a.m.	Some Recent Advances in Wash-Wear Research	J. D. Reid, CF, SU
9:30 a.m.	Effects of the Nature of the Crosslinking Agent Upon Cotton Fabric Properties	W. A. Reeves, Chief, CF, SU
10:00 a.m.	Intermission	
10:30 a.m.	Use of Divinyl Sulfone Adduct in Wash-Wear Finishes	C. M. Welch, CCR, SU

May 2, 1961		C. Norris Rabold, Chairman
11:00 a.m.	Imparting Crease Resistance to Cotton Fabrics with Vapor from HCl-Paraformaldehyde	J. D. Guthrie, CCR, SU
11:30 a.m.	Thermoplastic Cottons	C. M. Conrad, Chief Research Chemist, PF, SU
12:00 Noon	Luncheon Break	
		Lawrence L. Heffner, Chairman, N. C. State College, Raleigh, N. C.
1:00 p.m.	Flame Resistant Cotton	G. L. Drake, Jr., CF, SU
1:30 p.m.	Weather- and Rot-Resistant Cotton Products Preliminary Studies on Mixed Pigment Impregnations	R. J. Brysson, CF, SU
2:00 p.m.	Estimated Costs and In-Service Evaluations of Some New Chemically Modified Cotton Fabrics	K. M. Decossas, H. L. E. Vix, and E. L. Patton, ED, SU
2:30 p.m.	Interfacial Polyamide Treatment of Wool Fabrics to Provide Shrink Resistance	H. P. Lundgren and W. L. Wasley, WU
3:00 p.m.	Tour and Exhibits of Cotton Research (Busses courtesy Southern Regional Research Laboratory)	

U. S. DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Southern Utilization Research and Development Division
New Orleans, Louisiana

FOR IMMEDIATE RELEASE March 17, 1961

Cotton Utilization Research Conference Scheduled for May 1 in New Orleans:

Recent advances in cotton utilization research will be the subject of a three-day conference between industry and members of the Southern Utilization Research and Development Division research staff, beginning May 1 in New Orleans, according to an announcement by Dr. C. H. Fisher, Director of the Division.

Earl Heard, vice president, research, of West Point Manufacturing Co., West Point, Ga., has accepted an invitation to serve as general chairman for the meeting. Chairmen for the various sessions will be George S. Buck, Jr., technical assistant to the executive vice president, National Cotton Council of America, Memphis; Lawrence L. Heffner, Cotton Utilization Specialist, North Carolina State College School of Textiles, Raleigh, N. C.; Louis L. Jones, Jr., president, Canton Cotton Mills, Canton, Ga.; and C. Norris Rabold, Director of Research, Erwin Mills, Cooleenee, N. C.

The first day's program, beginning at 9:15 a.m. Monday, May 1, will be devoted to reports on research on fiber properties and mechanical processing of cotton. A. M. DUPre', Jr., Assistant to the Administrator of the Agricultural Research Service, Washington, D. C., will be the first speaker on the program, and will discuss improvement in cotton quality through research. R. A. Rusca, of the Southern Division, will describe recent advances in cotton

machinery development; R. J. Cheatham, Chief of the Cotton Mechanical Laboratory, will report on progress in this area of research; and Miss Mary L. Rollins and V. W. Tripp are to report on damage to the cotton fiber as determined through microscopical observation.

Four papers are to be presented at the afternoon session: "Drying and Cleaning Effects on Fiber Properties," by J. N. Grant, E. Honold, and F. R. Andrews; "Origin of Short Fibers in Cotton," by J. N. Grant, SU, and H. D. Barker, Crops Research Division; "Effect of Short Fibers in Cotton on Yarn and Fabric Properties and Spinning Performance," by J. D. Tallant, L. A. Fiori, and R. J. Cheatham; and "Blending -- a Means of Maintaining Quality in Cotton Products," by Mr. Fiori and G. L. Louis.

Tuesday morning Dr. J. David Reid, head of the Southern Division Wash-Wear Task Group, will lead off the wash-wear discussions with a paper on "Some Recent Advances in Wash-Wear Research." W. A. Reeves, Chief of the Cotton Finishes Laboratory, will report on "Effects of the Nature of the Crosslinking Agent upon Cotton Fabric Properties," and Dr. C. M. Welch will discuss divinyl sulfone adducts as wash-wear finishes. Dr. J. D. Guthrie is to report on wash-wear cottons through the vapor phase reaction with formaldehyde.

Dr. C. M. Conrad, Chief Research Chemist of the Plant Fibers Pioneering Research Laboratory, will close the morning session with a discussion of thermoplastic cottons.

Other types of chemical treatments for cotton will be taken up in the afternoon, with G. L. Drake, Jr., speaking on flame resistant cottons, and R. J. Brysson discussing weather- and rot-resistant

cotton products. K. M. Decossas will report on costs of the new chemically modified cottons, and H. L. E. Vix on fabric evaluations. A representative of the Western Utilization Research and Development Division, Albany, Calif., is expected to report on wool research findings there.

After the close of the formal program, the remainder of Tuesday afternoon will be given over to a tour of the cotton laboratories and inspection of some of the research products.

The third day of the conference is reserved for conferences of the individual advisers with laboratory chiefs and research scientists, and with the Division Director.

U. S. DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Southern Utilization Research and Development Division
New Orleans, Louisiana

FOR IMMEDIATE RELEASE April 11, 1961

Textile Industry Conference Set in New Orleans May 1-3:

Some 200 members of the textile industry are expected in New Orleans May 1-3 to attend a conference on recent developments in cotton utilization research at the Southern Utilization Research and Development Division of the U. S. Department of Agriculture. The conference is being held in conjunction with the annual conference of industry collaborators and cotton research administrators and researchers at the Southern Division.

M. Earl Heard, vice president, research, of the West Point Manufacturing Co., West Point, Ga., has been named general chairman for the meeting.

Those in attendance will hear reports on the latest research developments presented by members of the Southern Division's research staff. The first day's program will be devoted to fiber properties and mechanical processing. Louis L. Jones, Jr., president, Canton Cotton Mills, Canton, Ga., is chairman for the morning session, and George S. Buck, Jr., technical assistant to the executive vice president, of the National Cotton Council of America, Memphis, Tenn., is chairman for the afternoon meeting.

The second day's program will be given over to discussions of the chemical modification and finishing of cotton, with C. Norris Rabold, director of research, Erwin Mills, Cooleenee, N. C., as chairman of the morning session, and Lawrence L. Heffner, cotton utilization specialist, North Carolina State College School of Textiles, Raleigh, N. C., presiding over the afternoon session.

The closing day is set aside for conferences of the collaborators with individual scientists, and a meeting of the collaborators with Dr. C. H. Fisher, Director of the Division.

ATTENDANCE LIST

Cleveland L. Adams, Auburn University, Auburn, Alabama

J. T. Adams, Union Carbide Chemicals Company, South Charleston, W. Va.

William G. Ashmore, Textile World, Greenville, S. C.

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George S. Buck, Jr., NCCA, Memphis, Tenn.

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Malcolm Campbell, Dean, School of Textiles, North Carolina State College, Raleigh, N. C.

J. W. Carroll, Production Manager, Atlanta, Ga.

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Esther M. Cormany, School of Home Economics, Kansas State University, Manhattan, Kansas

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J. D. Crowder, Superintendent, Federal Prison Industries, Atlanta, Ga.

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